VOL. XV, NO. 3 SEPTEMBER, 1922

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

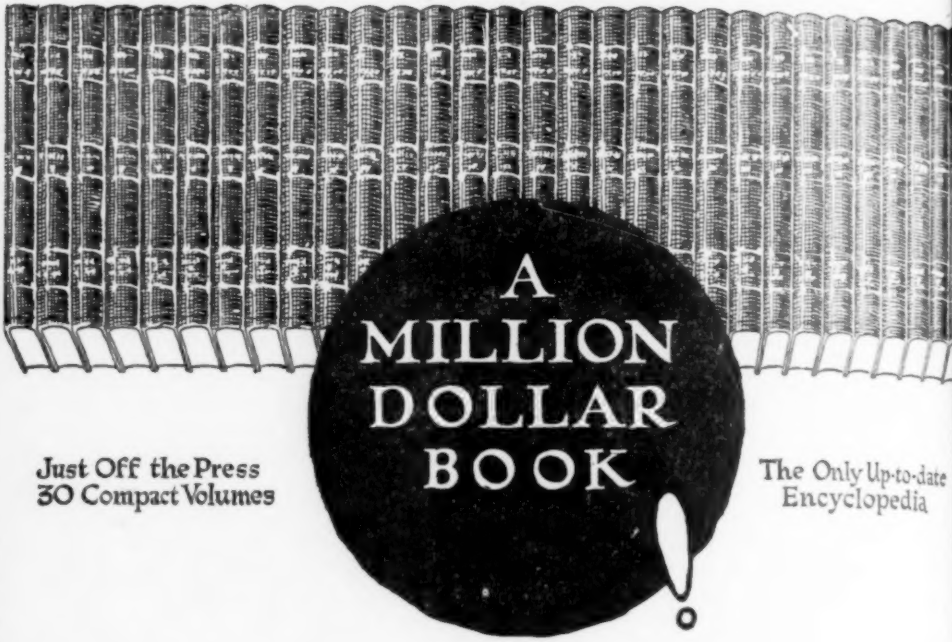
PUBLICATION OFFICE: 11 LIBERTY ST., UTICA, N. Y.

EDITORIAL AND BUSINESS OFFICE: GARRISON, N. Y.

New York Office: The Grand Central Terminal

Single Number, 50 Cents. Yearly Subscription, $5.00

Entered as second-class matter November 9, 1921, at the Post Office at Utica, N. Y., under the Act of March 3, 1879.



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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1922

THE REASONABLENESS OF SCIENCE[1]

By Professor W. M. DAVIS
HARVARD UNIVERSITY

A Fable of the Tides

ONCE upon a time—for science also has its fables—there dwelt a hermit on the shore of the ocean, where he observed the tides. He measured the period and the range of their rise and fall and, patiently tabulating his records, discovered that the tides run like clock-work. The interval between two high tides was determined to be about 12 hours and 26 minutes; the range from low water to high water was found to vary systematically, being greater one week and smaller the next, the total variation running its course in 14 days; more singular still, the high tides were found to exhibit an alternating inequality, such that, if they were numbered in order, the even-numbered would be stronger than the odd-numbered for two weeks and then the odd-numbered would be stronger than the even-numbered for two weeks; this cycle of alternating inequality completing itself in 28 days. The hermit then wishing to extend his observations, decided to travel overland to another ocean and learn whether the tides behaved in the same way there also.

Now at the same epoch, but far away in the center of a great continental desert, a recluse lived in a cave, thinking and reflecting. One problem in particular engrossed his thoughts. He knew Newton's law of gravitation, and he asked himself what other consequences ought to follow from it besides the revolution of the planets around the sun and of the moons around their planets. He at last convinced himself that if the earth and the moon attract each other, the moon must produce a system of what he called earth-deforming forces, disposed in such a way as to strain the earth's

[1] Oration delivered at the annual meeting of the Harvard Chapter of Phi Beta Kappa, in Cambridge, Mass., June 19, 1922.

crust, tending to raise it on the sides of the earth toward the moon and opposite the moon, so that at any one point on the rotating earth, the crust should be raised twice in a lunar day, or every 12 hours and 26 minutes; also, that similar but weaker earth-deforming forces produced by the sun should be combined with those produced by the moon so that the resulting total strains in the earth's crust would be stronger and weaker every 14 days; and furthermore, that as the moon is north of the sky equator for one half of a lunation and south of it for the other half—Alas, that you dwellers in roofed houses are so little acquainted with the sky as not to know of your own seeing that the moon's course does carry it obliquely across the sky equator and back again every month!—but as the moon does move in this manner, the recluse saw that the deforming forces which tend to raise the earth's crust at any point must exhibit a sequence of alternating inequalities every 28 days. And beside these rhythmic variations in a little more than half a day, in 14 days, and in 28 days, he worked out several other variations of even longer periods. But his calculations also showed that the rhythmic forces were too weak to deform the stiff earth's crust perceptibly. "If only," he thought to himself, "some large part of the earth's surface were covered with a deep sheet of water, surely the deforming forces would make the yielding water sheet rise and fall every 12 hours and 26 minutes, with a variation of range every 14 days, and an alternating inequality of rise every 28 days, and so on." He thereupon resolved to travel into other regions and learn, in case a vast sheet of water were anywhere discovered, whether it really did exhibit rhythmic changes of level in systematic periods such as, according to his calculations, it ought to exhibit.

Observation, Invention and Deduction

Curiously enough it happened that about this time the hermit reached a caravansery where he met an alert-looking individual who proved to be an inventor—not an inventor of machines but of hypotheses and theories and explanations. The hermit told him about the tides and their periodic variations, and asked: "What do you suppose makes them go?" The inventor thought a moment and then said: "Perhaps the tides rise and fall because Old Mother Earth is slowly breathing; or perhaps, inasmuch as you say the tides vary every 12 hours and 26 minutes, or twice in a lunar day, they may possibly be driven by the moon." "How can they be driven by anything that is so far away in the sky, and why should one moon make two high tides in one lunar day?" asked the hermit. Just then the recluse came in and, approaching the other two, inquired: "Can you tell me whether there is any-

where a vast sheet of water covering a large part of the earth?" "Yes, there is," said the hermit; "it is called the ocean. I have lived on its shores, observing the periodic rise and fall of its waters in the tides and I was just asking the inventor here if he could tell me how they are caused." The inventor repeated his suggestion that the tides might possibly be caused by a sort of earth-breathing, but that they were more probably caused by the moon. "Well, as to that," exclaimed the recluse, "I can tell you how the tides ought to run if the moon has anything to do with them. The moon ought to produce two high tides on opposite sides of the earth, so that as the earth rotates, the tides at any one point ought to rise and fall twice in a lunar day, as you say they do; not only so, they ought to be extra strong every 14 days at new moon and at full moon, because the sun also must have a share in producing them; and besides that, the high tides ought to show an alternating inequality in a period of 28 days; and"—The astonished hermit interrupted—"They do exactly that," he cried, "but how in the world did you know they do so, if you have never seen the ocean?" "I didn't know they did," replied the recluse, "but I was convinced that *if* the earth had an ocean its waters ought to have rhythmic oscillations of the kind I have described, because don't you see——" and he proceeded to explain his calculations.

Verification

"What are you men talking about?" said a sedate-looking onlooker of judicial aspect. So the hermit, the inventor and the recluse all repeated their stories to him. He pondered a while and then remarked to the inventor—"It looks very much as if your hypothesis about the moon's driving the tides were correct, for it is hardly conceivable that the consequences of lunar attraction, as thought out by the recluse, and the period of the tides, as observed by the hermit, could agree so well unless the moon and the tides stood in a veritable relation of cause and effect; but the hypothesis needs modification because, as the recluse has pointed out, the secondary variations of the tides show that the sun also has something to do with them." "But," interposed the recluse, "there should be, besides those already mentioned, still other periodic variations in the tides if they are really caused by the moon and the sun, and it will demand of the observer at least a year to detect some of the longer ones." "Take your time," said the judicial onlooker, "go back to the ocean and make a long series of records, not only at one point but at many different points on widely separated coasts; and come back here for a second conference 10 or 20 years hence. We may then reach a well established conclusion."

And thus it came to pass that, after long series of tidal observations had been made in many parts of the world, all the rhythmic consequences deduced from the moon-and-sun theory were so fully confirmed by their correspondence with the observed periodic variations of the tides in the ocean, that—in short, it all ended happily: all the world was convinced that the moon and the sun really do drive the tides.

The Four-Faculty Procedure of Modern Science

But the moral of the fable is yet to be told. The moral is that the observant hermit, the alert inventor, the thoughtful recluse, and the judicial onlooker represent not four different individuals, but only four different mental faculties in a single individual, the trained man of science, who uses his powers of observation to discover the facts of nature, his inventive ingenuity to propose various possible hypotheses for the explanation of the facts, his power of logical reflection to think out, or deduce, from each hypothesis, in accordance with previously acquired, pertinent knowledge, just what ought to happen if the hypothesis were true, and his impartial faculty of verification to decide which hypothesis, if any, is competent to explain the observed facts. In view of the leading part taken by these four faculties in scientific investigation, we may speak of science as involving a four-faculty procedure. But the fable must not be taken to mean that every scientist has all his faculties developed to the full strength needed for the best work; one man may be a patient observer but not active-minded enough to be a good inventor of hypotheses; another may be an ingenious inventor of hypotheses, but too impatient to be a good observer and too flighty to be a good deducer, and so on. Nor must it be understood that the several faculties work independently; as a matter of fact, now this faculty, now that is called into play in irregular sequence, and very frequently they are summoned into conference with one another. If it were not that the phrase is preoccupied in another connection, we might call such conferences "faculty meetings." Furthermore, it must be pointed out that replacement of mental deduction by experiment is essential in problems of certain kinds; that is, the faculty of invention is called upon, after proposing an explanatory hypothesis, to devise special artificial conditions under which natural processes shall themselves be permitted or constrained to determine the consequences of the hypothesis; but mental deduction usually accompanies or follows experimentation, and therefore problems into which experiment enters may still be included under four-faculty science.

The Fallibility of Science

Unfortunately, in all steps of science from observation to verification, mistakes may be made, errors may creep in. It would be profitable to examine some of the more common classes of errors into which scientific investigators are led by the imperfection of their faculties; and it would be still more profitable to set forth the safeguards by which the danger of making errors may be lessened. Brief comment on observation and verification may be made in these respects. Errors commonly associated with observation result from the unconscious extension of visible things into inferred things, and from the attempt to establish generalizations on too narrow a basis. Consciousness of the danger of these errors goes far toward eliminating them. The most common errors associated with verification are a tendency to adopt an imperfectly supported conclusion instead of maintaining a suspended judgment, and an unwillingness, indeed an inability to change an adopted conclusion after it has been invalidated by new evidence.

As to the latter cause of error it may be said that, if proficiency comes from practice, it would be almost worth while occasionally to lead advanced students to a false conclusion and leave them in it for a time, so that they might have actual practice in changing their minds when corrective evidence is later brought forward. Indeed, scientific training can hardly be regarded as completed until it has included the necessity of giving up a cherished opinion. The experience is distinctly an unpleasant one; it causes mental disturbance to the point of sleeplessness; but it is profitable in promoting the maintenance of a mobile state of mind. Time forbids further consideration of this aspect of scientific methods; but I must again emphasize the undeniable and regrettable fact that, in spite of all efforts in training and safeguarding the mental faculties, it is still impossible to avoid all errors, because scientists are fallible; for if mistakes can be made with respect to anything so manifest as visible facts of observation, they are still more likely to be made when it comes to the invisible facts of theory. The marvel is not that mistakes of both kinds are made, but that, in spite of man's undeniable fallibility, so great a body of scientific conclusions still holds good, especially with regard to what I have just called the invisible facts of theory. Let me say a few words on that point.

The Nature of Theorizing

There is a popular prejudice against the use of the inventive faculty, ordinarily called theorizing. Theorizing alone, mere theorizing, is certainly of little value; but trained theorizing in

proper association with trained observing is absolutely essential to scientific progress. The chief reason for this is that our observing senses are of limited power. We soon reach the conviction that many facts of nature elude direct observation, either because their medium is inherently transparent and intangible, or because their dimensions are submicroscopic, or because their time of occurrence lay in the irrecoverable past. And yet all of these unobservable phenomena are in their own way just as much a part of the natural world as observable phenomena are. If we wish really to understand the natural world, surely those of its phenomena which are not immediately detectable by our limited senses must be detected in some way or other; and the way usually employed is—theorizing. No single observable fact is a complete entity. The world is not so simply constituted. The deeper one inquires into the nature of an observable present-day fact, the more one becomes persuaded that it is in some way or other related to something else that, for the reasons just given, is not observable; and in such an inquiry one soon becomes convinced that the something else is, in spite of our not seeing it, or hearing it or feeling it, in short not sensing it, just as truly a fact of nature as the sensible fact from which our inquiry started out. The sensible facts are discoverable by our senses, the insensible facts by our thoughts. The invention of hypotheses is therefore nothing more than a mental effort to bring insensible facts into causal relation with sensible facts, and such an effort of correlation is praiseworthy even if it is daring.

Now hypotheses when first invented are as a rule not only incomplete, but are also without assurance of being true, especially with regard to insensible facts. Of course they must explain the observed facts that they were invented to explain; they would deserve no consideration at all if they did not do that! But before any one of several competing hypotheses is accepted as true, it must do more; it must explain facts that it was not invented to explain, facts that were perhaps not known when it was invented; and it must do this consistently with all previously acquired knowledge, so that the new explanation shall cohere with the older ones. Not until these exacting demands are satisfied should the correctness of even the best of several competing hypotheses be accepted. It therefore remains, after several hypotheses have been invented, to determine which one of them, if any, is right; that is, to determine whether the imagined insensible facts of any one of the hypotheses are truly counterparts of actual insensible facts. That important task is accomplished, as was shown in the tidal problem, by mentally deducing all the logical consequences of each

hypothesis and then matching them with appropriate sensible facts. If the consequences of a hypothesis are numerous, peculiar and complicated, and if, even so, they succeed in matching equally numerous, peculiar and complicated facts, a good share of which were unknown when the hypothesis was invented, then it is highly probable that that hypothesis is true.

Let me add that it is this demand for the verification of a hypothesis after its invention that especially distinguishes modern science from primitive science, as I shall later show more fully; and it is chiefly because of the demand for verification that the modern progress made in the daring search for insensible facts has been so great. Errors are still made, because scientists are still fallible; but instead of pointing, I will not say the "finger of scorn," but the thumb of reproach at science for having made and for still making errors, we should rather marvel at its successes, particularly in revealing to us the nature of the unseeable, insensible world, as in the inconceivably small subatomic electrons and ions which enter into the composition of the material substances of the world; or in the existence of the marvellously tenuous, elastic, and immaterial medium, named the luminiferous ether, by which radiant energy is conveyed through what we call empty interplanetary and interstellar space; or in the event of the past history of the earth's surface, which were visible enough in their time, but which are now irrecoverably invisible.

The Credulity of Science

It is not to be denied that much credulity is called for in this daring search for the unobservable facts of the natural world. Science, however, is not alone in credulously building up an unseen world to complement the seen world. That has been done by non-science also for ages past. But the credulity involved in the two cases is unlike. In the latter the credulity is whimsical, fantastic, irresponsible, incoherent; in the former it is orderly, controlled, rational, coherent. During the progress of the human race from savagery toward enlightenment, fantastic, incoherent credulity is slowly replaced by rational, coherent credulity. The belief in witchcraft is a good example of irrational credulity. Let me give you an equally good example of rational credulity. The solution of the tidal problem involves a belief in the force of gravitation, by which two bodies like the moon and the earth or the sun and the earth exert a pulling force upon each other. We are familiar with the exertion of a pulling force through material substance, as when one pulls a heavy body with a rope; but the attraction of the sun upon the earth is exerted through what appears to be empty space. Yet in spite of the absence of anything to pull with, the

sun's attraction is strong enough to pull the moving earth continually into the curved path of its orbit. How large a rope or cable do you suppose would be required to represent, in material form, the pull exerted through empty space by the sun on the earth? If the cable were made of ordinary telegraph wires, the wires would have to be planted all over the earth's disc about as close together as grass roots in a lawn, and even then the wires would be stretched almost to breaking strength in compelling the earth to turn from a straight tangent into its curved orbit. Scientific credulity accepts that marvel. It believes that that enormous pull is exerted by the sun on the earth through space that is empty of all material substance, even though no adequate physical explanation is yet found as to how the pull can be exerted. Credulity of a certain kind is therefore highly characteristic of science and of scientific men: it leads them to believe marvels quite as marvellous as any that were ever believed in unscientific ages.

The Scheme of the Geographical Cycle

Let us now turn to an altogether different example of scientific inquiry, a geographical inquiry concerning the distribution of plants and animals over the earth's surface. Climate is an important factor in controlling their distribution. Now climate varies not only from equator to pole but also with altitude above sea level. Lowlands are warmer and as a rule drier than highlands. But a lowland may, it is believed, be changed to a highland by the gradual upheaval of its part of the earth's crust; and it is believed further that a highland thus produced must in the course of time be worn down to a lowland again by the still more gradual processes of erosion. A warm lowland with a moderate rainfall may therefore be upheaved into a cool or cold highland with greater rainfall; and after the forces of upheaval have ceased, the cool and rainy highland may be very slowly worn down to a warm and less rainy lowland again. Evidently there must be changes in the flora and fauna of a region while it is undergoing these changes of altitude and of climate. As a lowland is raised into a highland and its climate modified, its former flora and fauna can not survive, because they can not accommodate themselves to the new climatic conditions. They are therefore replaced by immigrants from some neighboring highland or from some lower land nearer the pole. Likewise the occupants of a highland can not survive the changes of climate that take place as it is worn down to a lowland; they are therefore gradually replaced by invaders from some other lowland not too far away. It is instructive to note that these changes of the earth's surface, slow as they may be, are faster as a rule than the evolutionary changes of plants and animals. Hence, in

a long view of the earth one would see its plants and animals not only undergoing their extremely slow evolutionary changes, but also making somewhat less slow migrations, prompted by and accompanying the upheavals and down-wearings of its surface; and the present distribution of plants and animals is believed to be simply a transitory phase in this long succession of changes.

How different is this problem of the cycle of geographical changes from that of the tides. The rapid changes of the tides are directly observable; they are moreover periodic and their changes can therefore be observed over and over again; and both they and their cause are susceptible of quantitative mathematical treatment. The changes of the geographical cycle are so slow that they can not be followed, they can only be imagined; and there is no reason for believing that such cycles of change are accomplished in a definite period, nor indeed that any given cycle will run its entire course without disturbance; the downwearing of a highland to a lowland may be interrupted during its progress by a new upheaval. Moreover the asserted extinctions and invasions of plants and animals following the changes in the climate of their habitat are only inferences. In a word, this scheme of the geographical cycle is in its very nature highly speculative. Why then should credence be given to it? For the very simple reason that only by believing it can a host of present-day observable facts, inorganic and organic, be brought into reasonable relations. In short, the scheme of the geographical cycle is believed because it works; and therefore, like many other scientific conclusions, it is an excellent example of pragmatic philosophy. But how venturesome is a scheme in which the observed facts of to-day constitute so small a fraction of the total phenomena! On the other hand, for those who have the scientific faith to believe that such changes as those involved in the scheme of the geographical cycle have actually taken place in the evolution of the present aspect of the earth, how admirably does this scheme give us examples of invisible facts of theory! And in spite of their being deeply buried in the past, how wonderfully are those facts recovered, at least in their general nature, by taking that mental action which, although it does not add a cubit to our physical stature, does add immensely to our understanding.

The Nature of Scientific Demonstration

But what does a man mean when he says that he believes the scheme of the geographical cycle, with its imagined yet unseen changes of land forms and its inferred yet unobserved changes in the distribution of plants and animals. He ought not to mean that the truth of the scheme has been absolutely proved, but only

that it has been given a very high order of probability; for that is, as a rule, the nature of what is often called scientific demonstration. He ought to recognize also that many generalizations on which the argumentation of the scheme rests are likewise not absolutely proved: for example, the persistence of the present-day order of natural processes through hundreds of millions of years of past time; to say nothing of the unbroken continuity of time itself! Who can prove the truth of those generalizations in any absolute sense? Nevertheless one accepts their truth because he finds, after due inquiry, that they too appear to have a high order of probability.

Now what is the common feature in the problem of the tides and the problem of the geographical cycle, and in all other scientific problems, in virtue of the possession of which they deserve to be called scientific? Evidently not the subjects that they treat, for the subjects of scientific study are remarkably diverse. The common feature inheres not in the content of the problems but in their method; and the common feature of their method is the quality of reasonableness; that is, a spirit of free inquiry, in which no prepossessions are accepted which are not themselves open to scrutiny, in which the conclusions reached are followed wherever they lead, and in which a revision of conclusions is made whenever it is demanded by new facts. Science is therefore not final any more than it is infallible. It is a growth, and its growth is by no means completed.

Science had indeed only very gradually grown to be the four-faculty procedure that it now is. In very primitive times the mere observation of facts without inquiry as to cause was perhaps as far as science could then be carried; it was only a one-faculty procedure then. Somewhat later simple generalizations regarding facts that resembled each other may have been made; and the generalizations framed by individuals may have advanced to tribal generalizations. Indeed it seems quite possible that some such tribal generalizations of one-faculty science, for example, as to things that are good and bad to eat, may have been established by our anthropoid ancestors before they deserved to be called men. But even the most primitive tribes of men now living seem centuries ago to have advanced into a second stage of two-faculty science, in which the invention of explanatory hypotheses is added to observation and generalization. Even the lowest savages now known try to explain many of the things that they see by relating them to other things that they either see or do not see, and they thus establish to their own satisfaction relations of cause and effect. If the effect is explained by a visible cause, well and good. But if,

in the stage of two-faculty science, the effect is explained by an invisible cause, what then?

The Two-Faculty Procedure of Primitive Science

In striking contrast with present-day four-faculty science in which verification is so essential, the earlier two-faculty stage of science accepts its hypotheses without any adequate verificatory inquiry. Its explanations do not have to explain more than they were invented to explain, and they do not have to cohere with previously acquired knowledge. If they explain the facts that they were invented to explain, that is enough. Naturally therefore the two-faculty stage of science represents a phase of human development in which whimsical, incoherent credulity flourishes, the kind of credulity which I have already referred to as unscientific, because it is so unlike the orderly, coherent credulity of four-faculty science. But I now wish to treat that incoherent credulity in another way; to regard it as the inevitable accompaniment of two-faculty science, and hence just as appropriately an element of an early stage in the evolution of science as the rational, coherent credulity is of the present, more advanced stage. It is as if, between the primitive one-faculty stage, which was reasonable as far as it went, and the present four-faculty stage which seems to those who have reached it completely reasonable, there had been an unreasonable two-faculty stage in the evolution of science. The three stages are so unlike that one might hesitate to call them all scientific; just as one hesitates to give a single name to a caterpillar, a chrysalis and a butterfly: and yet the first two stages are in both cases the essential antecedents of the third. In any case the two-faculty stage of science was as reasonable as the two-faculty scientists could make it; and that is all we four-faculty scientists can say of our own stage.

The Natural History of Goodness

This may be made clearer by illustration. At the opening of my address I outlined the problem of the tides as one which modern four-faculty science has carried to a well established quantitative solution. This was followed by the problem of the geographical cycle which, although avowedly very speculative, has been advanced to a qualitative solution at least. I wish now to consider a third problem, which illustrates remarkably well the gradual development of inquiry in ancient times, and also the difference of certain conclusions reached by two-faculty science that was in vogue then from those reached by four-faculty science that is current now; and this problem has the further value of illustrating the optimism of science, for it leads to a conclusion concerning mankind that is

full of hope. The usual name for the subject of this third example is the science of ethics; I propose, however, to call it in general terms the natural history of goodness. There is nothing new in what I have to say on this old subject, although I may give a new emphasis to some of its aspects.

The facts which this branch of natural science treats are found in the body of opinion held by the different tribes and peoples of the world concerning things which they regard as right and wrong, that is, in their moral codes, and in the actions which they approve or condemn. Different people have different codes, and the code of the same people changes with the passages of time. Countless are the tragedies that have been enacted when a more powerful people, arrogantly assuming the justice of its own code, has ruthlessly violated the code of a weaker people. The theoretical side of the science includes a search for the sources of the different elements of each tribal or national code, for the processes by which the elements of a code are slowly modified, and for the forces by which good thoughts and acts may be fostered and bad ones suppressed. The natural history of goodness is therefore concerned with the concrete opinions and actions of ordinary men in commonplace, every-day life, and has nothing to do with the abstractions of metaphysics regarding absolute and eternal ideals. In that respect it might be compared with the natural history of mathematics, which would portray the efforts of early man in gradually and tentatively developing the multiplication table, but would have nothing to do with the metaphysical pre-existence and everlasting verity of 7 times 9 being 63. For in the same way the natural history of goodness would, if it could, describe the first recognition and the later modification of various ethical principles by certain peoples in certain places at certain times under certain conditions, but it would take no acocunt of the metaphysical view that all ethical truths are eternal, as if they had existed by themselves somewhere in the interstellar spaces of the universe for untold ages awaiting recognition.

The Ethics of the Children of Israel

The few illustrations of this great subject that I have time to present will be taken from the Old Testament, that marvellous record of the intensely human struggle made by a primitive and ignorant people in their advance from savagery to barbarism. How very primitive they were; and in no way more primitive than in candidly recording their frequently scandalous behavior! A more sophisticated people would have taken care to conceal their errors, but the Children of Israel were savagely naïve. Their early books,

those of the Pentateuch and the ones next following, contain abundant material for study in announcements concerning things held to be right or wrong as affecting food and hygiene, property in land, cattle and slaves, safety of life and limb, and social intercourse. The good things are sometimes directly stated, but they are more often to be inferred as the opposites of bad things that are prohibited or punished.

None of the announcements are more striking than those which have to do with the taking of human life as a punishment for various kinds of wrong-doing. In the time of Noah this important problem was treated simply and concisely: "Whoso sheddeth man's blood, by man shall his blood be shed" (Gen. ix, 6). But that early pronouncement was elaborately modified in the time of Moses and afterward. It was then still ordained in general terms that "thou shalt give life for life;" but it was also ordained on the one hand that, besides offenses of bloodshed, various other offenses should also be punished by death, and on the other hand certain offenses of bloodshed should not be punished by death. As to the first, a number of offenses are listed, among them being for example the smiting or the cursing of one's father or mother, for which a man "shall surely be put to death" (Ex. xxi, 12-17); and here the use of the word "surely" seems to imply that the Children of Israel were sometimes too lax in the punishment of such offenders. As to the second group of offenses, a time came when careful distinction was made between intentional and accidental manslaughter. Thus if one man thrust another out "of hatred, or hurled at him, lying in wait, so that he died," that man is a manslayer and "the avenger of blood shall put the manslayer to death, when he meeteth him." This command is emphasized by the suggestive addition: "Ye shall take no ransom for the life of a manslayer (Num. xxxv, 20, 21, 31). But a man who "killeth his neighbor unawares, and hated him not in time past; as when a man goeth into the forest with his neighbor to hew wood, and his hand fetcheth a stroke with the axe to cut down the tree, and the head slippeth from the helve, and lighteth upon his neighbor, that he die;" then the man is not worthy of death, inasmuch as he hated not his neighbor in time past (Deut. xix, 4, 5, 6). At an early time one witness seems to have been sufficient to prove a man to be a manslayer; but in later time it is said: "At the mouth of two witnesses or three witnesses, shall he that is to die be put to death; at the mouth of one witness he shall not be put to death" (Deut. xvii, 6). What good, homely common-sense this is!

Ancient and Modern Views of Israelitic Ethics

It would appear from these and many other passages, especially those concerning their wars, that the Israelites must have been in-

deed a violent crew; but it appears also that they made very explicit and frank record of their views concerning right and wrong. Now if we examine their records as contributions to the natural history of goodness in an era of two-faculty science, we ought to ask ourselves among many other questions, not only what were the views of the Israelites concerning good and evil, but also how they gained their views, and how they came to establish, as a means of controlling their actions for the common weal, rewards for good and punishments for evil. As a matter of fact, investigation of this large subject has been carried on earnestly for a century or more, and in a truly scientific spirit; that is, reasonably and with an open mind. I propose to compare, or rather to contrast, the conclusions reached by modern students of the subject under their four-faculty procedure, with the opinions held by the Israelites themselves under their two-faculty procedure.

The Israelites' view was, if we are to take their records literally, that their understanding of good and evil as well as their decrees for the reward of good and the punishment of evil, came to them by supernatural revelation; and this view was adopted by all Christendom in later centuries. The modern view, more and more widely adopted now, is that the Israelites derived their knowledge and their decrees concerning good and evil in a perfectly natural way from a perfectly natural source; namely, from their own perfectly natural experience, the same source from which all other human knowledge is gained. The decrees and commandments were not sudden acquisitions, but merely expressions of the morals and customs gradually developed among the people and formulated by their leaders. In comment upon these two views it should be noted that the ancient view originated among a primitive, ignorant, cruel, self-centered people, very ready to adopt extraordinary, even supernatural explanations for simple occurrences, because being in the stage of two-faculty inquiry they did not apply, they did not know how to apply independent verificatory tests to their hypotheses, but naïvely believed them if they explained the things they were invented to explain; and that the modern view has been gradually developed in later times by many broadly informed students of human history and human nature, who have gathered a vast amount of information not only about the ancient Israelites but also about many other primitive peoples, ancient and modern; students who have examined that information reasonably and in a spirit of free inquiry, who have at every step in their inquiry done their best, according to the procedure of four-faculty science, to verify their explanations and who have therefore reached their conclusions carefully and critically, intelligently and sympathetically.

Grounds of the Modern View

Some persons here present probably hold the earlier one of the two views, and some the later one; but however my audience is divided in that respect, it is more likely a unit in not habitually looking on the Old Testament as affording material for the scientific study of the natural history of goodness, and as therefore not regarding it as affording fit illustrations for the third example of scientific inquiry, which I am now outlining. There seem nevertheless to be cogent reasons for looking on it in this way. One of these reasons is that the Old Testament, especially its earlier half, gives so excellent an idea of the manner of life led by the Children of Israel. The records are as a whole unconcealedly human in telling of friendships and quarrels, of generosities and meannesses, of honorable acts and of dishonorable acts; hence they give an invaluable picture of the views of a primitive people on moral questions.

Furthermore, when the books of the Old Testament are read—particularly when they are read in a polychrome edition which distinguishes the various sources from which the successive books are compiled—the understanding of good and evil there recorded is seen to exhibit very distinctly an evolutionary progress, such as is found from studies of other peoples to be characteristic of the natural history of goodness in general; witness the citation already made about manslaughter; witness also the declarations concerning food. In the time of Noah it was said: "Every living thing shall be good for you" (Gen. ix, 3); and this is much more primitive than the later declaration in the time of Moses, when sharp discrimination was made between the cloven-footed, cud-chewing animals which might be eaten and other kinds of animals which might not be eaten (Lev. ix; also Deut. xiv). It may be noted in passing that a belief in the evolutionary development and progress of mankind greatly simplifies the vexatious problem of the existence of evil in the world; for much of the forbidden behavior or wickedness of a later era is thus seen to be only a continuation of the permitted behavior of an earlier, less advanced era.

Finally, the Old Testament records of the Children of Israel may be taken as affording proper material for the study of the natural history of goodness because they show the Israelites to be so very like other savage races. They justified themselves as a chosen people; they ascribed bad qualities to their enemies whom they really resembled rather closely; they saw mysterious omens in commonplace events; they regarded dreams as messages from an extra-human source; they were miraculously visited by good and bad spirits; they took their own very human convictions to be revelations and commandments from their local tribal god; and

to that god they attributed, but in a higher degree, their own very human qualities; not only wisdom and goodness and power, but also forgetfulness, repentance, hatred and revenge. In all this the Children of Israel are so like other primitive tribes that they must evidently be studied just as other primitive tribes are studied.

Supernatural and Natural Interpretations

Now in reviewing the reasons thus briefly set forth for regarding the records of the Old Testament as affording fit material for the study of the special branch of human evolution here under consideration, it is interesting to notice that the same reasons lead to the rejection of the older view that the knowledge of good and evil gained by the Israelites was derived from a supernatural source, and to the acceptance of the modern view that it was simply a summation of their own human experience. Indeed, when the Mosaic books are read in a rational, scientific spirit, without prepossession, the marvel is that they can be interpreted in any other way. That the Israelites should have introduced supernatural elements into their records, as when they explained the Ten Commandments by revelation, is inevitable in view of what is now known concerning the natural history of goodness among all primitive peoples in the stage of two-faculty science; and that they should have accepted these supernatural elements as true is thoroughly characteristic of the incoherent credulity that prevails among primitive peoples under the two-faculty method of establishing beliefs in unseen things. But that the supernatural elements of these ancient and primitive beliefs should have been accepted as true by all Christians during nearly all the centuries of Christendom is nothing less than marvellous; or perhaps I should say, would be nothing less than marvellous did we not know that through all those centuries a great part of the beliefs of Christendom were dominated by two-faculty science.

Consider, for example, the decree concerning a servant who has earned his freedom by six years of service, but who then still loves his master, his wife and his children so much that he does not wish to go out free and leave them: in that case "his master shall bring him . . . to the door, or to the door post; and . . . shall bore his ear through with an awl; and he shall serve him for ever" (Ex. xxi, 6). Boring a hole through a man's ear with an awl would seem to be a very simple, a very human way of marking him. It is therefore unduly credulous to believe that this and other similar decrees had a supernatural source, even if they are preceded by the introductory statement: "And the Lord said unto Moses, these are the judgments which thou shalt set before the Children of Israel" (Ex. xxii, xxiii). No such introductory statement is

given before similar decrees in Deuteronomy xv. One is indeed tempted to think that the words, "And the Lord said . . . " by which various paragraphs in the Pentateuch open, were hardly intended to be taken literally.

THE TREATMENT OF ENEMIES

If anything more is needed to show the utterly human nature of the Mosaic decrees, it is found in the narrow limitation of the commandments: "Thou shalt do no murder . . . Thou shalt not steal;" for manifestly these rulings applied only to neighbors and fellow tribesmen, not to enemies. As to enemies, commands were repeatedly given, as if from the Lord, to kill them wholesale, even to their women and children; and to steal from them everything they possess. The advance of the Israelites to the promised land under Moses and Joshua is a horrible story of rapine and bloodshed; the plain and pitiless story of ruthless savagery. Samuel is probably remembered by most persons nowadays chiefly as a gentle little boy, who, wakened from his sleep by the call of the Lord, answered, "Speak, for thy servant heareth" (I Samuel iii, 10); yet it was Samuel who, when grown to manhood, was possessed with the idea that the Lord gave him a message, a hideous message, to Saul, to smite the Amalekites "and utterly destroy all they have, and spare them not; but slay both man and woman, infant and suckling, ox and sheep, camel and ass." And because Saul and his army, after killing every man and woman, infant and suckling, spared Agag the king of the Amalekites and kept the best of the oxen and sheep for themselves, "then came the word of the Lord unto Samuel, saying, It repenteth me that I have set up Saul to be king . . . and Samuel was wroth" and had Agag brought before him and hewed him in pieces with a sword (I Samuel xv, 3, 11, 33).

A GREAT DEBT TO SCIENCE

We have sadly to admit that horrors of those kinds have been frightfully characteristic of human progress from savagery and barbarism all over the world; and also that such horrors have been frequently regarded by the people who committed them as acceptable to or directed by their local tribal deities, as they conceived them; but it must have been a heavy burden to Christian faith to believe that the loving, fatherly God of the New Testament is the same god who led Joshua in his bloody wars and who told Samuel to give that hideous message to Saul. It is a great blessing that the progress of modern scientific inquiry and the spirit of rationalism that has grown with it have relieved Christian faith of that burden. Science has truly benefited the world in many ways, but it may be doubted whether any other benefit derived

from scientific rationalism is so great as the liberation of Christianity from the reproach which it fully deserved so long as it included a literal acceptance of all the teachings of the Old Testament, in spite of Christ's preaching a religion of brotherly love in the New Testament.

But you may ask, is it truly to science that the world owes that great benefit? Has science indeed anything to do with these religious matters? It has of course to do with the earth and the stars, with plants and animals, with steam and electricity; but by what right does science concern itself with questions of good and evil? It does so by the same right, precisely the same right that it studies the tides as governed by the moon and the sun, and the slow changes of earth's surface when lowlands are raised to highlands and when highlands are worn down to lowlands. For the observant and thoughtful study of mankind discovers many facts of opinion and facts of action concerning things that are regarded as good or bad; and all those facts, which together with their causes and consequences are included under the natural history of goodness, are just as properly open to scientific inquiry, that is, to unprejudiced, reasonable inquiry, as any other facts in the world. Nevertheless, the feeling that science is a trespasser on such ground is often met; and also the allied feeling that science is too cold and hard to deal with such questions. Let us see.

The Conflict of Religion and Science

First, as to science being a trespasser when it touches questions with which religion has traditionally dealt. Much has been written about what is called the conflict between religion and science. The cause of that conflict lay not in the trespass of science upon the proper field of religion, but in the trespass of religion upon the proper field of science. Religion attempted, while thus trespassing, to dictate beliefs concerning the age of the earth, the origin and the antiquity of man, and many other mundane matters. What is more natural than that science, as it developed, should enter into conflict with the trespasser; and what more manifest now than that, in so far as geology and organic evolution and other similar subjects are concerned, the conflict should have resulted in the complete conquest of those subjects by science from religion! This wholesome defeat of religion, or rather of the misguided defenders of what was long thought to be religion, would not have taken place had the advice of St. Augustine been followed. He wrote long ago: "It very often happens, that there is some question as to the earth or sky, or the other elements of this world . . . respecting which one who is not a Christian has knowledge derived from most certain reasoning or observation, and it is very disgrace-

ful and mischievous and of all things to be carefully avoided, that a Christian speaking of such matters as being according to the Christian Scriptures, should be heard by an unbeliever talking such nonsense, that the unbeliever perceiving him to be as wide of the mark as east from west, can hardly restrain himself from laughing" (Thus quoted in Osborn's "From the Greeks to Darwin").

Will not a modern St. Augustine arise and make a similar statement concerning the natural history of goodness? I wish he would, for all human thoughts and acts are, like human anatomy and physiology, the product of natural evolution. Just as surely as all questions of a geological or astronomical or biological nature have now been permanently acquired from religion by their respective sciences, so conquest will be made of all questions concerning right and wrong by that division of science which concerns itself with the natural history of goodness as a matter of purely human experience, in contrast to goodness as a matter of supernatural revelation. Two great and growing, though still young branches of modern science will contribute powerfully to this conquest; they are eugenics and psychiatry. I hope that some speaker before this society a hundred years hence will review the practical contribution by that time made to human betterment by these young giants.

True Science is neither Cold nor Hard

As to the other idea that science is too cold and hard to deal with moral questions, there is to my regret some ground for that opinion. It is probably based on the behavior of certain scientists who, having made, as far as they have gone, no serious misjudgments, have not been enlightened by the baptism of acknowledged error, and who are therefore harshly overconfident of the correctness of their conclusions. They introduce their would-be rigorous methods of thought into daily intercourse with their neighbors, and are logical when they ought to be genial, argumentative when they ought to be sympathetic; in short, they are very tiresome fellows, and they do science a disservice. No wonder that a gentle-minded person would hesitate to trust scientists of that sort with decisions on delicate problems of right and wrong! But on the other hand, even the best of science is judged cold and hard with little reason by certain sentimental and emotional persons who, reclining on soft couches of prejudice and downy pillows of preference, are intellectually too indolent to face the problems of life fairly and squarely; too unreasonable to subject their opinions to candid scrutiny; too undisciplined to change their beliefs even in the light of compelling evidence. They know nothing of the calm and clear spirit of free inquiry; they are unwilling to follow free

inquiry to an unwelcome conclusion; for example, they reject the philosophy of evolution because, as they fastidiously phrase it, they do not like the idea of being descended from monkeys. I do not believe we need take their condemnation of science as being cold and hard any more seriously than their rejection of evolution because they do not like it.

No, the natural history of goodness lies manifestly within the field of scientific inquiry, and true scientific inquiry will not be either cold or hard in reaching conclusions about it. Scientific inquiry will, indeed, remove from the minds of intelligent thinkers at least, a very cold and hard religious view of ancient origin to the effect that punishment, either in this world or in hell, is the best means of suppressing evil; and will also remove, I hope, the equally primitive view that rewards, either in this world or in heaven, are the best means of promoting good. And let me note in passing that the dependence of the Israelites largely upon punishment, and frequently upon very harsh punishment, as a means of improving human behavior is another of the many evidences for the human origin of their code of morals. It is natural enough that crude views regarding the wish for reward and the fear of punishment should have been characteristic of ignorant ancient peoples, just as they are still characteristic of unintelligent modern peoples. But it is clear enough to-day that fear of punishment is often unsuccessful in the prevention of evil, and that expectation of reward, especially of distant reward, is not very successful in the promotion of good. There is great need of finding something better than reward and punishment as a means of improving the world.

Can the scientific study of the natural history of goodness discover something better? It ought at least try to do so; and in the belief that it will do so lies the optimism of science; but it will take a long time to reach results. For as I have already noted the natural history of goodness includes a study of the forces by which good thoughts and actions may be encouraged and strengthened, and bad ones inhibited. How will the study proceed? Undoubtedly by the standard scientific method of observation, invention, deduction including experiment, and verification; in a word, reasonably. The facts to be studied are, of course, plainly enough very unlike the visible and periodic variations of the tides as controlled by the moon and the sun, and very unlike the present distribution of plants and animals as a consequence of the long past, invisible, non-periodic changes of the geographical cycle; but just as certain appropriate means have been found for solving those unlike problems under the four-faculty proceedure of modern science, equally appropriate means will, it must be hoped, be found for the

solution of this human problem. Efforts toward its solution by the current methods of improving personal and public morals as a part of religious training will of course be continued; but I hope they may be supplemented by systematic instruction in ethics as a branch rather of natural history than of philosophy in schools and colleges.

Goodness Taught By the Case Method

In such instruction the nature of the subject should not be set forth so much in impersonal generalizations as by the "case method," the same method which Louis Agassiz so successfully introduced into the study of zoology, which Langdell with equal success applied to the study of law, and which is now increasingly employed in the Harvard Graduate School of Business Administration as the best means of inculcating sound business principles. Indeed, the natural history of goodness lends itself remarkably well to this method of presentation; for its facts may be set forth in collections of concrete examples of various kinds of behavior, concerning which the pupils may make their own judgments and generalizations; and such collections of examples may be graded from elementary to advanced, so as to afford excellent material for individual exercises from early school years onward. But in the meantime, while such instruction is going on, the specialists in this branch of natural science must extend their investigations by carrying their observations over a great number of individuals, and by devising ingenious experiments concerning all sorts of pertinent conditions.

Observation will be difficult because it will have to take account of the endless diversity in the dispositions and capacities of boys and girls, men and women; but it must not be neglected. Experiments will be intricate, for they will operate slowly and will be hard to follow; but they must not be omitted. Both observation and experiment must be directed in particular to determining how far the love of goodness and the hatred of evil can be cultivated and strengthened; and also how far the cultivated love of goodness and the spiritual happiness that comes from good deeds, together with the cultivated hatred of evil and the spiritual distress that comes from bad deeds, may be trusted as guides to conduct, in preference to rewards for good behavior and punishment for evil-doing; and in this investigation due regard must be had to the age and the nature and the environment of the individual. Great results should not be expected, however, until a way is discovered to strengthen the will; and I believe the best way to do that will be to give it opportunity for action in a carefully devised and wisely supervised series of graded exercises, running all through school and college years. We are making a very serious mistake in not introducing

systematic exercises for the development of the will, that is, of self-control, in our educational system.

Objection will probably be urged against the proposition to teach goodness as a branch of natural history. It will be said that the omission of all mention of God is fatal to its acceptance and its success. In my judgment, our relation to the Infinite should be excluded from natural history and assigned to religious instruction, where it should be treated with the utmost reverence; while the natural history of goodness should be taught just as other branches of natural history are taught, entirely apart from any idea of special creation or any miraculous interference with the order of nature. But it should be taught with a gentleness, a delicacy, a sympathy not to be imagined by persons who think of science as cold and hard, and of scientists as chiefly engaged in hammering rocks, dissecting animals and pulling plants to pieces. Those who enter this branch of natural history, either as investigators or as teachers, must strive to conduct themselves with the wisdom of the judge, the true insight of the poet, when need be with the tenderness of a mother, and always with the infinite patience of evolution itself. It is a great field and it deserves the devotion of the best minds.

The Greater Faith of Devout Believers

In order to illustrate the reasonableness of science I have told you something of the tides as a very specific, quantitative, mathematical problem of four-faculty science; and I have sketched the scheme of the geographical cycle as a highly speculative problem, in the qualitative treatment of which the four-faculty procedure has nevertheless been encouragingly successful. Finally I have outlined the natural history of goodness in order to exemplify the broad range of moral questions over which the four-faculty method of scientific inquiry may be hopefully extended. You will, I trust, accept the tides and the geographical cycle as problems of some interest and importance; but I hope you will regard the natural history of goodness as a much more interesting and a much more important subject of scientific study, particularly as an illustration of the reasonableness of science. If you do so, I beg that you will encourage the cultivation of that branch of natural history and favor its introduction, by means of the case method, into our educational system. There will be of course, as already intimated, those who will say that, just as in replacing special creation by evolution, so in replacing the revelation of goodness by its experiential development, we are acting as if we had lost faith, as if we were unbelievers; but for my part I hold that we are thus acting as most sincere, most earnest, most devout believers, and as having the greater faith.

ASTRONOMY IN CANADA[1]

By Dr. OTTO KLOTZ

DIRECTOR OF THE DOMINION OBSERVATORY, OTTAWA

LET me first extend greetings from my native country Canada to our nearest and closest neighbor and friend—you of the United States. Although two flags wave over our countries, there is only one celestial vault to cover us; the same stars smile on you as on us, and we both appeal to them to help solve the riddle of the universe. Our aims and our aspirations are, I think, the same—the uplift of our people, the utilization of all our resources for the common weal, the widest distribution of the amenities of life, but all founded on the eternal gospel of work.

I think we will find that the origin of all national observatories has been to supply a distinct want or need in the affairs of the nation concerned. So it was with the Royal Observatory at Greenwich and so it was with us. You will recall that it was essentially the question of determining longitude at sea that decided Charles II—in spite of the evil reputation he earned for himself—to command the Rev. John Flamsteed "to apply himself with care and diligence to improve the Table of the positions of the Fixed Stars and Moon to find out the much desired Longitude at Sea, for the perfecting the Art of Navigation." And so was founded the Royal Observatory in 1675. No thoughts of abstract science were in the minds of its founders. It was founded for the benefit of the Royal Navy, and that is its first object to the present day, although its field of activity has vastly expanded and comprises many lines of research. Now a few words as to the origin of the Dominion Observatory, the national observatory of Canada.

The original Dominion of Canada as born on the 1st of July, 1867, comprised the four provinces of Nova Scotia, New Brunswick, Lower and Upper Canada, or Quebec and Ontario. In 1871 British Columbia entered the Dominion, and amongst the terms of federation was that Canada was to build a railway to and through the province to the Pacific Ocean, while British Columbia on her part would convey to the Dominion all lands held by the Crown within 20 miles of the contemplated railway. I may say here that there

[1] Subject matter given in an illustrated ex-tempore address before the Academy of Arts and Sciences, Brooklyn, on February 28, 1922.

was some difference of opinion as to what 20 miles meant along a naturally very sinuous railway of over 500 miles through a sea of mountains. There was of course only one correct interpretation, and that was the area covered or swept by a 20 mile long arm attached at right angles to each side of a moving train.

It was decided by the Dominion Government that the lands to be acquired from British Columbia were to be coordinated with those of the northwest, the survey of which was based on astronomic positions. Although the rectangular system of surveys, the division of lands into sections, townships and ranges was copied from the United States, we in so far improved on it that our system is connected and is a unit, extending from the Lake of the Woods to the Pacific, and from the International Boundary of the 49th parallel to the Arctic Ocean, while in the United States the surveys of the individual states, where the rectangular system applies, are quite independent of each other, and hence lack coordination.

May I here, as I have mentioned the 49th parallel, say a word about its survey, as the astronomer played an important part therein.

You know it's so easy for diplomats sitting about a table to decide the fate of countries and their boundaries. With regard to the latter they are often in blissful ignorance of the geography involved or of the people affected. Certainly nothing could look nicer on paper than a parallel of latitude, which has so simple a definition, curving around the earth. Laying it down on the ground, however, is quite another story. The two astronomers engaged in this international work clearly recognized difficulties that might and would arise in observing for latitude and came to an understanding how to deal with the matter.

The understanding—and a very sensible one—was that the observed latitude was to govern, quite apart from the error that may be involved due to the deflection of the plumb line. The observations themselves, about 50 years ago, being practically devoid of error, were made with present-day accuracy.

The line zigzags, responding to the varying attraction or displacements of the zero of the level from normal. The greatest displacements were the ones to the north of 600 feet, due to the attraction of the Cypress Hills; and the other to the south of 800 feet, due to the attraction of the Sweet Grass Hills in Montana close to the boundary. That is, within a distance of less than a hundred miles we had a difference of 1,400 feet in the gravitational effect due to the unequal distribution of matter along the boundary line. This unequal distribution is not always visible as manifested by the hills spoken of; it might be hidden underneath the surface.

To return to the story of the evolution of the Dominion Observatory: The lands of that 20-mile railway belt in British Columbia were to be coordinated with the land system of the northwest immediately east of the Rocky Mountains. Meridians or parallels could not be projected over the mountains, so the railway itself on the eve of completion was made a base line by a special and very accurate survey. To secure its geographical position a number of astronomic stations were established along the line, and to them was joined the special railway survey. Thereby every part of the line became known by its geographical coordinates and hence surveys could be started where required for mines, timber or other purpose, and expressed in sections, townships and ranges. Thus was born astronomy, practical astronomy, in Canada as a function of the government. That little lamp lit in 1885 was tenderly cared for, fostered and developed and its usefulness extended so that 20 years later the government built the Dominion Observatory, the national observatory of Canada, fully equipped for astronomical and astrophysical work as well as for some branches in geophysical work—seismology, terrestrial magnetism and gravity, about each of which I shall make some brief remarks.

To the general public a dome is a *sine quâ non* for an observatory, and yet the fundamental work does not require it. By fundamental work I mean the determination of the accurate position of the sun, the moon, the planets and stars. And that is essentially the work of national observatories for the use of navigators, explorers and astronomers engaged in other lines of work. This work is done with the meridian circle. As its name implies, it is mounted in the meridian and is only movable therein.

The big telescope, the equatorial that can sweep the whole heavens from its dome, is particularly adapted for answering the question of the little rhyme, "Twinkle, twinkle, little star, how I wonder what you are?" That's it, what you are, not where you are (the meridian circle tells that), but what you are, what gases compose your being, have you a companion, what is your temperature, your mass?—there are queries which the equatorial with its attached spectroscope answers.

Our equatorial 15" is at present used exclusively for the determination of radial velocity of stars forming binary systems, by means of the spectroscope. You all know the spectroscope, how the prisms in it break up the light into its constituent rays, each with its particular wave length, to be photographed on a narrow glass plate, together with some standard light. The motion of a star causes its spectrum to be shifted to or from fixed lines or fixed spectrum, depending upon the approach or recession of the star

relative to the earth. The principle is the same as the change in pitch of a locomotive whistling when approaching or receding from a station. A marvel of the spectroscope is the separation of stars into a binary system when the most powerful telescope fails to see but one object, apparently the presence of only one star.

The success that had been attained in the determination of radial velocities led the government to secure a telescope of a far greater light-gathering power and to mount it where the climatic conditions were more favorable than at Ottawa, and particularly where there was an assurance of more clear nights in the year than obtained at the federal capital. Hence was built the Dominion Astrophysical Observatory at Victoria, British Columbia, and the results already achieved there have fully justified the decision. The largest equatorials are invariably reflectors. The one at Mount Wilson, California, has a diameter of 100 inches, while ours, the second largest, has a diameter of 72 inches or 6 feet. Perhaps the most spectacular and beautiful telescopic object in the heavens is the great nebula in Orion. Then there is the great nebula in Andromeda, the brightest one in the sky. Next we see the ring or annular nebula in the constellation of Lyra, which may be seen with even a small telescope. Contemplating these nebulæ, many questions flood the mind to which but very few answers are as yet available. The spectroscope as usual forms our interlocutor and gives us knowledge from the bright lines in their spectrum that they are incandescent gases under low pressure.

Thus by means of the spectroscope revelation after revelation is unfolded, and the fleet-footed messengers traveling at the rate of 186,000 miles a second come to us after their long, long journeys, some hundreds of years, many even thousands of years and bring the welcome news of their distant homes. Let me make a philosophical and perfectly logical statement based on what I have just said, and that is that no astronomer could give you absolute assurance that any stars that you may see to-night are really there, for the news from the nearest one takes over four years to reach us: that is, it would keep on shining for us four years after its extinction.

Another wonder in the heavens is found in the dense globular clusters, and of these the most splendid in the northern sky is the great cluster in Hercules, also known as Messier 13, in which there are more than 50,000 stars.

Mentioning this number may surprise some or most of you; when on a clear moonless winter night you look on the sky, you will be tempted to say, "What myriads of stars stud the celestial vault." That is poetic license. If you could count them, you

would never get as many as 3,000, possibly 2,000 as seen by the naked eye, for there are not over 5,000 stars in the whole sky, northern and southern hemispheres, that can be seen with the unaided eye.

When you board a ship in New York bound for some foreign port, you have the utmost confidence of reaching your destination, but I am sure it never occurs to you that the astronomer has anything to do with it. Yet it is his labors that supply the captain with the data, as found in a nautical almanac, to guide the ship over the watery waste. This astronomic work is undertaken by all national observatories, the determination of fundamental star places. We also engage in this work. The instrument used is called a meridian circle, so named because it is mounted in the meridian, to which its motion is confined. During my own time the work of the astronomer has been greatly assisted by electrical devices. When I began observing—tell it not in Gath—half a century ago, we recorded by eye and ear; that is, with pencil in hand and listening to the beats of a chronometer or clock the transit of a star across the thread of a telescope was recorded. And what do we do to-day? The astronomer at the telescope turns a micrometer screw following the star, and in an adjoining room his observation is not only recorded but printed in hours, minutes and seconds and hundredths of a second on a continuous strip of paper, which can be copied at leisure the following morning. This certainly removes a lot of the drudgery of former days.

The meridian circle is essentially the instrument that furnishes time; although our daily life is regulated by the sun, yet the accurate time is invariably obtained from the stars, which can be far more accurately observed than can such a boiling cauldron as the sun. Has it ever occurred to you that every time you pull out your watch and look at the time you are paying silent tribute to the astronomer? So does every factory whistle that summons to work and every church bell that summons to devotion. The time of all trains in the country is derived from some astronomer—the silent watcher of the skies.

Although most investigational and research work is done amongst the stars, yet the most important celestial body for us, outside of our own earth, is the sun. Every living thing on this earth, vegetable or animal, life in any form, is but converted solar energy, crystallized sunbeams. We are nothing but animated sunbeams, which is a very good reason for giving us sunny dispositions. When we once know more about the behavior of the sun, how the firing is done and the stoking, what material is used for heating, and whether there is a rhythmic periodicity in the ac-

tivities, when we know some of these things we will be able to forecast the conditions upon the earth.

The sun is under daily scrutiny, and is attacked from different angles. We are studying its rotation and problems involved therein, by means of the coelostat. The earth being a solid, every part of it revolves in the same time; but such is not the case with the sun, as it is a gaseous mass, in consequence of which the equatorial parts revolve faster than parts north or south thereof. The period of rotation of the former is about 26 days, while the polar regions require 4 to 5 days longer. The principle involved in determining the rotation of the sun is the same as that employed in determining the radial velocity of stars, the displacement of the lines in the spectrum caused by the moving body. Hence, if we obtain simultaneously the spectrum of the two limbs or edges of the sun, the one edge through the rotation will be approaching us, while the other one will be receding; the amount of displacement of the lines of the spectrum resulting therefrom will give us a measure of the speed of rotation. Occasionally you see here the Northern Lights, not quite as brilliantly as we have them in Canada, which sails more closely under the Great Bear or Dipper. These Northern Lights or the Aurora Borealis are a manifestation of solar activity, shooting out negatively charged particles into space and those intercepted by the earth, which at its distance from the sun can stop but the minutest fraction of the matter radiated, give the electric glow to the outermost regions of our atmosphere, encountering there hydrogen and helium, giving the whitish greenish tinge to the phenomenon. When the electrically charged particles penetrate deeper and into the region having the presence of nitrogen, the color becomes reddish.

We are engaged too in the study of relative star magnitudes and the variability of their light by photographic means. It seems scarcely necessary to point out that magnitudes determined photographically and by the eye are not necessarily, in fact not generally, the same. The rays of light that are most effective for vision are not the same as those most effective for photographic purposes. For the latter the rays of shorter wave lengths, those towards the blue or violet end of the spectrum are most active in producing a photographic image.

In the foregoing we have given but the briefest outline of the purely astronomic work carried on in the observatory itself, but we engage too in field astronomic work, which was required in the vast expanse of Canada in which up to recent times there were few accurate surveys, and hence the accurate position of points or places was necessary to put Canada properly geographically on the map.

We use a Cooke portable transit of 3 inches clear aperture, and a cement pier is always built for mounting it. The instrument is used both for latitude and longitude work, and such an instrument it was I carried with me around the world some years ago, when I completed the first astronomic girdle of the world, wiring the British Empire together astronomically. Whenever the electric telegraph is available we use it for the determination of longitude. We always connect up our standard sidereal clock at Ottawa with the place where longitude is to be determined even when thousands of miles away, as in British Columbia. But when there is no telegraph line we now resort to wireless. This is a very recent innovation in astronomic work, and we applied it extensively last season in the Mackenzie basin, due to the discovery of oil and the necessity of surveys, which had to be based on astronomic coordinates. Let me but indicate the principle involved in this wireless longitude work. The wireless expert with his outfit by chronometer records the arrival of wireless time signals from anywhere; in the above case he recorded those from Balboa, San Diego, Annapolis, San Francisco, Honolulu and Cavite in the Philippines. At Ottawa with our wireless outfit we record the same or at least some of the stations. The astronomer who is with the wireless expert furnishes him with the accurate local time when the signals were received. Comparison later on with Ottawa shows the difference of time between the two places; hence the longitude. It is to be observed that although the signals received are time signals—but most of no high degree of accuracy—we treat them as arbitrary signals, simply as signals noted accurately at two places. The question of the origin of the signal comes into consideration by a very minute quantity, *i. e.*, the difference in time it takes to reach the Mackenzie and Ottawa, as the velocity of transmission of the wireless or Hertzian waves is 186,000 miles a second, being the same as that of light.

May I relate a little incident of the Mackenzie on our wireless. It is not astronomic, far from it, but rather worldly. On the 2nd of July last (it was on a Saturday) there came flashing over the earth news in which many people, even nations, were interested, and that news was as promptly and as soon received by our expert in the boreal regions of the Mackenzie as it was probably here in New York, so near the source. To couch it in astronomic terms, the news may be stated that in the binary system Mr. Carpentier was the eclipsed variable; period 4 revolutions in 12 minutes.

By the hyperboreans our expert was looked upon as one suffering from moral obliquity, but time later accorded him the appellation of the prophet of the Mackenzie.

Yes, the Dempsey-Carpentier fight was heralded in the Arctic regions about as soon as in Brooklyn.

The Dominion Observatory participated with Paris, Washington and Greenwich last summer in a wireless longitude determination for Australia in connection with the meridian boundary, 129° East, between South Australia and West Australia. The wireless signals were sent from the Lafayette station at Bordeaux and from Annapolis, and we recorded both.

I may mention that there is under consideration an international wireless longitude campaign around the world, by means of which we expect all countries to link up their longitudes with this international net. We expect to attain such accuracy that a repetition, say in 50 or 100 years, will reveal a bodily shifting of crustal masses, such as the continents, a circumstance that is believed to be and to have been in process for ages. This means that, for instance, America is moving away from Europe. In this international work Canada expects to cooperate, and she is already taking part in the International Astronomical Union which meets in Rome next May, and for which the speaker has been chosen delegate to represent Canada.

Beside the above purely astronomic work in which the Dominion Observatory is engaged, other scientific work falls within its sphere, consequent to the evolution of such work in Canada. We shall now make a rapid review of that work, which may properly be designated geophysics—comprising seismology, terrestrial magnetism and gravity.

Seismology, dealing with earthquakes, we may call the newest of the sciences, for it is only within recent years that we have obtained reliable records of earthquakes, so that we can locate them in unknown regions or in the ocean with a fairly high degree of precision. To give this a more definite meaning let me say that if we have a decent earthquake—one that gets a good grip on the earth to give us a clean record—it can be located, no matter how far away, say within 30 miles. And furthermore, we can determine the actual time to within two or three seconds. The actual time of the occurrence of a destructive earthquake in the Imperial Valley, California, was better determined from earthquake records thousands of miles distant than obtained on the spot.

Fortunately for the determination of the distance of an earthquake three different kinds of waves are simultaneously propagated. Two of them travel through the earth, *i. e.*, dip down into the earth, while the third confines itself to the surface, and each has its own velocity. We may compare these waves to three messengers, starting at the same time to spread the news of the earthquake. From many well-known quakes and their records we have

learned the speed of these messengers; two of them have a variable speed—the deeper they delve into the interior, any way to a depth of about a thousand miles, the faster they go. It is obvious, therefore, if we know the difference of time that it takes any of the two messengers to reach us, we know how far they must have traveled to produce that difference of time; hence we know the distance to the earthquake or epicenter, as it is called. To illustrate the principle in another way: An express train and a freight train leave a certain place at the same time, with an average speed of 45 and 30 miles respectively. You note their arrival in New York and find that the freight arrived ten hours later than the express, which will show that each had traveled nine hundred miles, *i. e.*, the starting point was 900 miles from New York. Quite simple. But what isn't always so simple is to read the record, the seismogram, to tell when the second and third meessengers arrived; the first one is generally easy to read because it begins from a state of quiescence of the instrument, but the other two take experience to decipher the hieroglyphs. It's a wonderful story these messengers write on our photographic record; they tell us where they have been, what the nature of the material is through which they passed, its density, its elasticity, a story as fascinating as that of Homer's "Odyssey," but not so easily interpreted. Seismology is the new science that gives and brings us direct evidence of the interior of the earth, and it has definitely shown and proven that the interior of the earth is not and can not be liquid, although at a very high temperature, because through a liquid our second earthquake wave, which has transverse motion, could not be propagated; one can not propagate transverse motion in water, but one can propagate longitudinal motion such as sound waves have, and this is the nature of the first wave to arrive. In a solid both kinds of waves, however, are propagated.

As to the cause of earthquakes: An earthquake is the release of stresses to which the earth is subjected. These stresses are manifold. Some are cumulative like constant denudation, transport of material from the land to the sea; some are seasonal like the polar accumulation of snow, and there are stresses due to the rotation of the earth, temporary loading by atmospheric pressure, to mention but a few of the contributory causes. Their occurrence or adjustment to equilibrium naturally is effected at the parts least able to resist the stress, and these are along fault lines, old sores in the earth's crust that are not thoroughly healed—healed by first intention, as the surgeon would say. We may, therefore, say very broadly: "No fault lines, no earthquakes." Also the newer geological formations where things have not settled

down so permanently are more subject to quakes than the older ones. The prediction of earthquakes is by no means a chimerical proposition, in broad outlines, at least.

Before leaving this interesting subject may I be pardoned for saying the Seismological Tables published by the Dominion Observatory are universally used in America and to some extent elsewhere.

As a by-product of the seismograph we have found that it records the pulsation of the ocean waves, *i. e.*, we in Ottawa record every wave of the Atlantic that impinges on the coast from Cape Hatteras to Newfoundland. The period of these waves varies from about 4 to 8 seconds, and on the seismogram they look like saw-teeth. These pulsations are transmitted through the crust of the earth. We have been able to link up these microseisms, called micros for short, with areas of low barometer on the Atlantic Coast. At Ottawa we are about 500 miles from the nearest sea coast, and it seems incredible that we receive through the earth these pulsations of the ocean. We have built and installed at Chebucto near Halifax an instrument which I christened "undagraph" or wave writer, which counts and records every wave of the broad Atlantic reaching the coast of Nova Scotia there, and that record or undagram we correlate with the corresponding seismogram at Ottawa.

The next subject in geophysics of which the Dominion Observatory has charge is terrestrial magnetism. That means the determination of the three magnetic elements, declination or variation of the compass as known to the public, inclination or dip and the magnetic intensity. Our work extends from the Atlantic to the Pacific and we have occupied some five hundred stations at each of which these magnetic elements have been determined. The variation of the compass is the element most wanted—the surveyor needs it, so does the explorer, the navigator and many others. When the poet writes "as true as the needle to the pole," he is guilty of poetic license of a serious kind. If a sea captain were to accept that statement he would never reach his destination. In our work we find for instance on the east coast of Canada the needle points 35° to the west of true north and on Vancouver Island 25° to the east, that is, a range of 60° over Canada, two-thirds of a right angle. It is very obvious that for those that use a compass it is very essential that its declination from true north be known. Unfortunately this is not a constant quantity, but is subject to an oscillating daily change and a slow secular one, both of which are quantities that we determine and apply.

In order to assure accuracy we standardize our instruments twice annually. The most accurate time is furnished by means of a pendulum clock. But why does the pendulum vibrate, or

pendulate, to coin a necessary verb? "It can't help itself" would scarcely be a scientific reply. It is the attraction of the earth that tends to restore it to its normal suspended position, the line of action of the earth's gravitational force. This force is affected by the rotation of the earth and the combined effect we call gravity.

The earth is not a sphere; hence points on the surface are at varying distances from the center. Again the centrifugal force due to rotation is greater in the equatorial regions than north and south thereof; in short, for every latitude there is a particular force of gravity, so that a pendulum that would swing or vibrate seconds in Ottawa would not do so here in Brooklyn. It would lose time here. You see you haven't got as much pull here (I am not speaking in a political sense) as we have in Ottawa, but you are more apt to fly off the handle, to use a cant expression, because nearer the equator. From the above statements it becomes evident that the pendulum, an invariable pendulum, gives us a means for determining the relative force of gravity on the earth, and thereby the accurate figure of the earth, its ellipticity, its flattening, as well as anomalies in the distribution of matter in the crust of the earth. This line of investigation is carried on too by the Dominion Observatory and we have about fifty stations distributed over Canada. The period of the pendulum, that is, the time of swing, which is about half a second, is determined to the one tenth-millionth of a second of time; let me repeat ten-millionths of a second of time, and this order of accuracy is shown when observations are repeated at the same place and the interagreement is limited to the units of the seventh place of decimals.

We now know the figure, *i. e.*, ellipticity, with a high degree of accuracy so that we can readily compute what the theoretical force of gravity should be for any given latitude; hence observations there will show the divergence or anomaly for that place, which means that there is an anomalous distribution of matter in and about the crust of the earth. When we speak of crust of the earth, we mean a thickness of about seventy-five miles, which brings us to the stratum of equilibrium or compensation.

All mountains practically float in the earth, the ten or twenty thousand feet or more that they tower above sea-level are not supported by the crust it couldn't do it but they float like an iceberg does in the ocean, which displaces as much water as its own mass above and below water.

These gravity observations have disclosed some interesting facts about what is hidden underground, by the amount of gravitational force or pull that the hidden mass or masses exercise. If there are huge deposits of iron ore, for instance, gravity would be increased, while large deposits of oil or gas or salt would have the opposite

effect. The pendulum thus becomes a scientific divining rod. We may well say—a peculiar concatenation—from the stars we bring to earth accurate time, and that time we use to express gravity, and from the latter divine oil. Perhaps it is fairer to state that the positive statement of the pendulum is when there is an excess of gravity, oil can *not* be present, for that always involves a defect of gravity.

But there is a more delicate and more sensitive instrument for measuring differential gravity, and that is the torsion balance, by means of which actual areas can be mapped out underground occupied by oil or gas or salt, which has recently been achieved in Europe, especially in Hungary. I am glad to state that such an apparatus is now being built for the Dominion Observatory, and it will be, I believe, the first in America for that purpose.

I shall refer to one other geophysical investigation in which we were engaged. Sir George Darwin many years ago concluded that the earth was subject to daily physical tides, beside those of the ocean, *i. e.*, that the earth was squeezed, was deformed by the action of the moon, which is the main factor in our ordinary tides.

Darwin tried to measure the minute quantity, but failed on account of disturbing factors on the surface of the earth. Hecker of Potsdam succeeded by having his instrument in a deep shaft beyond the effects of the daily heating of the earth, in obtaining a value, but there was the anomaly, found too by the Russian Orloff, that apparently the earth was more readily squeezed in a north and south direction than in an east and west direction. The question was referred to Professor Love, probably the foremost exponent in questions of elasticity, but no satisfactory solution was obtained. It was believed that possibly the situation of the observing stations with reference to the ocean might play a part by the gravitational effect of the tide or heaped-up waters upon the horizontal pendulum which was the instrument used, and also by this same mass of water bending the ocean floor and producing slight tilting of the instrument. To settle this the International Seismological Society decided to establish several stations widely differing in their positions with reference to oceans. Canada was assigned a station. The war intervened, and we never met again. However, the problem was attacked by Michelson of the University of Chicago and brilliantly carried out on the grounds of the Yerkes Observatory and in quite a different manner, by observing in 500-ft. 6-in. pipes partly filled with water the change of level. For measuring the minute quantities an interferometer was used, that is, the wave lengths of light were the measuring

rod. It was found that the earth responds practically instantaneously to the action of the moon. The earth as a whole has about the rigidity of that of steel. The surface of the earth rises and falls about a foot twice a day, due to lunar and solar attraction. We are sitting on a long "teeter"—6,000 miles long, with a period of a little over twelve hours—unconsciously teetering. It doesn't seem much, yet in it is bound up the constitution of our earth, and of all objects in the universe what concerns man more than the earth?

And now I have done. I have given you a brief outline of "Astronomy in Canada" the title of my address, together with other scientific work carried on by the Dominion Observatory. Euclid's definition of a point is that which has position but no magnitude—with Canada it is about the reverse with much emphasis on magnitude. We are trying to give it position—a prominent place on the map of a progressive world—a place in the sun—and I am sure you good people to the south of us, who have been basking in sunshine these years, will welcome the kindred spirit from the north, where we are trying to advance knowledge and advance the various fields of development in which we are engaged, so that our work may be a credit to Canada and a benefit to mankind.

THE TAR-BABY STORY AT HOME

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I

ABOUT thirty years ago the late Dr. Joseph Jacobs pointed out that the "Wonderful Tar-baby Story" of *Uncle Remus* has a parallel in a tale of the Buddhist Jātaka-book, where the most salient feature of the Negro story, the "Stick-fast motif, occurs.[1] Since then students of folk-tales have discussed that story with an almost undue respect for his enticing theory that it originated in India, passed to Africa in very early, perhaps prehistoric, times, spread over that great continent, and at last came to our shores deep-rooted in the souls of our Negro slaves.

What is more, since Dr. Jacobs first expressed his opinion, additional evidence has become available seeming to support at least the first part of his thesis, namely, that India is the ultimate home of the story, although other parts of his proposition have been variously modified.[2] For example, it has been suggested that the story did not reach Africa until comparatively recent times, say the sixteenth century, when it was taken there by Portuguese sailors. Latest, a well-known American folklorist has found the Tar-baby story in the Cape Verde Islands attached to the "Master Thief" cycle of tales—a cycle first presented to the Occident by Herodotus in his account of the robbery of King Rhampsinitus' treasury. On the basis of this discovery, she has suggested a theory that the Tar-baby was originally a part of the Master Thief tale, that they both came from India to Western Asia and Africa, and proceeded thence to Africa. There the Tar-baby feature was clipped or detached from the larger story and has since maintained an independent existence.[3] The idea is ingenious, but it is too much based on unprovable hypotheses to be convincing.

[1] Pañcāvudha-jātaka (Jātaka 55). Dr. Jacobs' remarks may be found in the following of his books: *The Earliest English Version of the Fables of Bidpai*, Introduction, p. xliv; *The Fables of Æsop* (Caxton's edition), vol. 1, pp. 113 and 136; *Indian Fairy Tales*, story of "The Demon with the Matted Hair."

[2] *E. g.*, see Dähnhardt, *Natursagen* 4, 27ff.

[3] E. C. Parsons in *Folk-Lore*, 30: 227. Her theory is untenable: (1) Herodotus' tale is not necessarily to be derived from an Indian source, for it

But the main question, that of Hindu origin of the Tar-baby, still remains unchallenged, and yet it is one that may well arouse scepticism.

The story has been reported in print oftener from Africa, including the Cape Verde Islands, than elsewhere—twenty-two times according to my own account, which is doubtless not quite complete—and this, too, in spite of the fact that African folk-lore has been less fully explored than that of India. Nor is there any part of Africa where it has not appeared, as far as I know, unless it be Egypt. It has been brought to light ten times among American Negroes, fourteen times among American Indians, seven times in India, and twice in the Philippines.[4]

Of these fifty-five versions fifty-two are "folk-tales" in the strictest sense of the word, that is, they are tales current orally among the illiterate folk, that have been secured by collectors from *viva voce* narration; further, they have been collected within the past sixty years. The other three versions are "literary," being found in professed works of literature, and come from India. The oldest of these three may be earlier than the dawn of the Christian era, for it is included in the *Samyutta Nikāya*, a division of the Southern Buddhist canon containing a number of religious discourses ascribed to the Buddha. The second is that known to Dr. Jacobs, a story of the fifth century Jātaka-book, which is a work portraying the Buddha's experiences in a number of previous existences. The third is a brief parable in a medieval Jain text, also religious, called the Parsistaparvan.

The story generally appears in a fairly well stereotyped form, showing a clever animal, in a few instances a man,[5] engaged in thieving, that escapes all efforts to catch it until the injured party —another animal or man—fashions as a trap an image made of

can be assigned an earlier date than any version of the Master Thief found in India; (2) No version of the Master Thief from India has the Tar-baby attached to it; (3) the Cape Verde Island tale is merely the usual tale contaminated by the Tar-baby idea, or at least the Stick-fast motif.

[4] For a list of references to the Tar-baby see Parsons, *l. c.* But add the following: (1) for Africa: Barker and Sinclair, "West African Folk-Tales," p. 71; Nassau, "Where Animals Talk," p. 23; *Folk-Lore*, 10: 282; 20: 443; 21: 215; (2) for India: (*a*) literary: Samyutta Nikāya, 5: 3, 7; Parisistaparvan, 2: 740; (*b*) oral: *Indian Antiquary*, 20: 29, and 29: 400; Gordon, "Indian Folk Tales" (2d ed.), p. 67. Mrs. Parsons has already noted the other versions from India, namely, that of the Jātaka-book (literary) and Bompas, "Folklore of the Santal Parganas," p. 325 (oral). For the valuable reference from the Samyutta Nikāya I am indebted to Dr. E. W. Burlingame.

[5] The Cape Verde Island stories and the Jātaka, but in the latter case the hero is not a thief (see discussion below).

some sticky substance, such as wax, resin, rubber, tar, or bird-lime, which the thief mistakes for a living being. Often the image is that of a female, thus subtly calculated to play to the sex impulse of the offender, who is always a male.[6] Anxious to become acquainted with this stranger, the thief accosts him (or her), but persistently receiving no reply to his overtures, he strikes the image and sticks fast, caught successively by hands, feet and head. (This is the Stick-fast motif.) There is usually a sequel in which the hero by a clever trick effects his escape. The only versions which depart strikingly from this general pattern are the three literary versions from India.

II

The case for India as the home of the Tar-baby story rests in general upon two arguments. The first was thirty years ago the major premise of nearly all studies in the history of folk-tales; it is that "India is the home of stories." Hence any version of a story that appeared in India was regarded as being truly "at home" there, and further as being the most original version of that tale. We now think differently. We concede that many stories of wide vogue were born in India; but we likewise maintain that many other stories were probably born in Egypt, Sumeria, Mesopotamia, Greece, China or other lands. No country ever had a monopoly in the manufacture of fiction; and only the most stubborn Indophile would argue otherwise. Hence there is no compelling *a priori* ground for looking upon India as the home of the Tar-baby.

The second argument, however, is more cogent. It may be stated thus: "Because the Stick-fast motif, the heart of the Tar-baby story, occurs in India at a time almost two thousand years earlier than it can be proved to have existed elsewhere, we must infer that both the motif and the story originated there." At first sight this reasoning seems unanswerable. But is it? May it not rest largely upon accident? It is true that we have no occurrences of the motif or the story at the beginning of the Christian era among the Negroes, the American Indians or the Filipinos, but for that matter we have no stories at all recorded for these peoples from that early time. The fact is that none of these three peoples

[6] The various forms of the story are classified by Parsons, *l. c.* The version in which the victim is attacked through the sex impulse is the more penetrating psychologically and perhaps the older. The same is perhaps true of the fable of "The Ass in the Lion's Skin." In the Pañcatantra the ass is destroyed because the sight of a she-ass arouses his innate lecherousness and he brays. (To the Hindus the ass is the lecherous animal *par excellence*.) In some other secondary versions, notably the Jātaka, the ass merely feels fear and brays.

has a literature; hence the first reports we have of their fiction come from our own investigators working in modern times. Yet no folklorist would say that these folk were without popular tales two thousand years ago; to do so would involve the rejection of the very corner-stone of folklore studies.

In brief the case for India is based for the most part on a general theory that often fails in specific instances and on a further line of reasoning that is three-fourths *argumentum ex silentio*. What we really need to substantiate a claim for India is these two things: first, proof that the Stick-fast motif and the Tar-baby story have a settled place in Hindu fiction; and, secondly, a definite tracing of their course from India to the other lands where they exist. As it happens, both of these things are lacking.

For neither the story nor the motif has a marked place in Hindu fiction. Look, first, at the three literary versions, remembering to keep them distinct from the modern oral versions. In these three instances we see the motif present, although in every case set in a story vastly unlike that of the Tar-baby. The oldest, that of the *Samyutta Nikāya*, says that there was in the Himalayas a pleasant place where men and monkeys lived. There a hunter, to catch the monkeys, used to smear their paths with a sticky ointment. Those monkeys that were intelligent and not greedy, when they saw the ointment, would avoid it. But when a foolish, greedy monkey saw it, he would grasp it with his hand and then he would be caught. To release his hand, he would grasp the ointment with his other hand; and it too would be caught. Thinking that he would release his hands, he would kick, but his foot would stick fast. So also would his other foot. Then he would bite, and his mouth as well would be held tight. Thus, "caught at five points," he would be taken by the hunter and killed.

This tale is merely a religious parable with the moral attached that he who is ensnared by sin is held ever tighter and tighter until as last he is destroyed. The Jain apologue of the Parisistaparvan is only a poor retelling of this, wherein the moral, however, is more specifically, "Avoid women!" The remoteness of these parables from the Tar-baby story is apparent. In neither of them is the victim a thief; in neither of them is the sticky ointment or pitchblend made into an image or doll; in neither of them is there the escape.

The other literary version, that of the Jātaka-book, is very different from these two, although it also has only the Stick-fast idea in common with the Tar-baby. It tells how the Bodhisatta (the Future Buddha), a prince skilled in the use of five weapons, encounters a notorious monster named "Sticky-hair." The prince

attacks him with fifty arrows, but these all stick harmlessly in the demon's hair; so too his sword, his spear and his club. Enraged, he strikes the monster with his hand, but it, too, is caught tight. He strikes with his other hand, and it likewise is caught. He kicks, his feet stick; and finally he butts with his head, and that as well is held fast. But, even though unable to move and apparently at the demon's mercy, the prince betrays no fear. "A very lion of men is this prince!" thinks Sticky-hair. "How is it," he asks, "that you have no fear of death?" "Why should I?" replies the Bodhisatta. "Every life must have its end. Moreover in my body is a sword of adamant that will chop your inwards into mince-meat; and if you devour me, my death will involve yours also." Convinced, the demon frees him.

This story, which perhaps contains a Buddhist satire on Brahman ascetics and their characteristic matted hair, is also not according to the Tar-baby type. The hero is a man—the only instance where this is the case except in the distinctly secondary version from the Cape Verde Islands, in which the Tar-baby story has become ancillary to the great Master Thief tale. Further, the hero is not a thief; nor does his enemy entrap him with an image, but instead uses his own matted hair—another unique feature. The escape is not by the subtle type of ruse common to the Tar-baby story but by a bald, and rather unconvincing, "bluff."

Clearly these literary tales have but little in common with the Tar-baby story of fifty other versions; they merely exhibit an application of the Stick-fast motif that is after all based upon simple observation of the qualities of pitchblend or matted hair, and arose in India quite outside of the Tar-baby milieu. It may well be that there is no genetic relation between them and the prevailing type.

But the case does not rest here. In addition there are a number of negative considerations that are of weight. If the Tar-baby story originated in India, we should at least expect such a gripping story to maintain a vigorous existence there. But it does not; it seems sterile. For, in the first place, the modern versions in India are not to be connected with those in the ancient literature. In one of them, for example, a farmer, to catch a jackal, buries a wax doll, the size of a baby. The jackal, thinking the grave contains a delicious corpse, digs up the doll and is caught.[7] In another tale the god Mahadeo, seeking vengeance upon a tricky jackal, fashions an old woman of wax on whose arm he places a basket of sweets. These the jackal endeavors to steal and is held fast.[8] The

[7] *Indian Antiquary*, 29: 400.

[8] Gordon, "Indian Folk Tales" (2d ed.), p. 67.

other two modern tales are equally dissimilar from the literary versions and correspondingly close to the general type. Indeed, all four of these modern tales, none of which was reported more than twenty-five years ago, are to be traced back to African sources, having come into the country either directly with the Negroes located chiefly at Bombay or else indirectly with the *Uncle Remus* stories that Occidentals tell to the natives and even translate into the local tongues.[9]

In the second place, there is no evidence that India has given the Tar-baby story or the Stick-fast motif to those of her neighbors whom she has so generously enriched from her literary treasures. Vast numbers of Hindu stories have been taken to Tibet and China in literary form, similarly to Persia and Arabia, but in none of these collections, as far as I know, nor for that matter anywhere in the literatures of these people, does either our story or our motif appear.

The whole crux of the matter on India's side is that neither the story nor the smaller motif seems to grip the Hindu mind; they do not appeal. The religious parables were almost stillborn; and the oral fables themselves are already moribund, being but pale, anemic specimens in comparison with the fullblooded, vigorous tale of the Negroes.

We must, therefore, count India out.

III

Having rejected India, we must now determine, if possible, which of the other lands where the Tar-baby story occurs is its birthplace. The task should not be hard. Obviously, it is not with the American Indians, for there is no means by which they could have sent the story to Africa. On the other hand, it is almost axiomatic that they have received it with many more of their folk-tales from the Negroes, often directly, in other cases through Spaniards, Portuguese, or other Europeans. The Filipinos can be rejected on nearly the same grounds and with the same degree of certitude; while the Portuguese in the Cape Verde Islands seem to have got it from the Negroes. There is left only Africa.

And Africa is eminently suited to fill the needs of the situation. First of all, it is a plausible center for the story's radiation. Slaves brought it thence to this continent; other Negroes, or perhaps the *Uncle Remus* books, have taken it to India in modern times; still other Negroes, or possibly Spanish sailors, have planted it in the

[9] See an illustration reprinted from one such translation facing page 300 in Julia Collier Harris's "The Life and Letters of Joel Chandler Harris."

Philippines. These are the only people among whom it has yet appeared, to the best of my knowledge, but if it should at some time appear among other peoples, I am confident that it will be easy to uncover its tracks back to Africa.

But more important is the fact that the Tar-baby is the story that more than any other holds the Negro's mind, and it holds his mind more than it does the mind of any other people. Three fifths of the "genuine" versions are his. All negroes know it and love it. A friend living near Baltimore tells me that he once had a cat named "Tar-baby." The suggestive power of this name was so great that an old colored servitor of his, merely on seeing the cat walk across the yard, would be thrown into violent fits of laughter. Other friends have told me of Negro servants who were acquainted with the Tar-baby story, and that too not from reading. The story is the common property of the black race. It is for them, as it were, the climax of a great animal epic, the grand theme of their fiction.

Fundamentally there is no reason why the Negro should not be the creator of the tale. He has created others; at least he tells a number of stories that seem unknown to other peoples.[10] Once created the tale was bound to live and wander just as perseveringly, though perhaps not so widely and quickly, as one that arose in India or Babylonia or Egypt; for vitality and travel are prime qualities of folk-tales. Hence it has in time become one of the Negro's few contributions to the general culture of the world.

[10] For example, the story of the two animals that make a hunger wager. The one that can go without food the longer is to secure the prize, which is frequently the hand of some female.

SOCIAL LIFE AMONG THE INSECTS[1]

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Lecture III—Bees Solitary and Social

TO those who are not entomologists the word "bee" naturally signifies the honey-bee, because of all insects it has had the most delightful, if not the longest and most intimate association with our species. Of course, the key to the understanding of this association is man's natural appetite or craving for sweets and the fact that till very recently honey was the only accessible substance containing sugar in a concentrated form. It is not surprising, therefore, that man's interest in the honey-bee goes back to prehistoric times. He was probably for thousands of years, like the bears, a systematic robber of wild bees till, possibly during the neolithic age, he became an apiarist by enticing the bees to live near his dwelling in sections of hollow logs, empty baskets or earthen vessels. Savage tribes keep bees to-day and within their geographic range we know of no people that has not kept them. They figure on the Egyptian monuments as far back as 3500 B. C., and we even know the price of strained honey under some of the Pharaohs. It was very cheap—only about five cents a quart.

The keeping of the honey-bee could not fail to excite the wonder and admiration of primitive peoples. It was at once recognized as a privileged creature, for it lived in societies like those of man, but more harmonious. Its sustained flight, its powerful sting, its intimacy with the flowers and avoidance of all unwholesome things, the attachment of the workers to the queen—regarded throughout antiquity as a king—its singular swarming habits and its astonishing industry in collecting and storing honey and skill in making wax, two unique substances of great value to man, but of mysterious origin, made it a divine being, a prime favorite of the gods, that had somehow survived from the golden age or had voluntarily escaped from the garden of Eden with poor fallen man for the purpose of sweetening his bitter lot. No wonder that the honey-bee came in the course of time to symbolize all the virtues—the perfect monarch and the perfect subject, together constituting the perfect state through the exercise of courage, self-sacrifice,

[1] Lowell Lectures.

affection, industry, thrift, contentment, purity, chastity—every virtue, in fact, except hospitality, and, of course, among ancient peoples bent on maintaining their tribal or national integrity, the fact that bees will not tolerate the society of those from another hive was interpreted as a virtue.

With the passing centuries the bee became the center of innumerable myths and superstitions. It was supposed to have played a rôle in the lives of all the more important Egyptian, Greek and Roman divinities. Among the Latins it even had a divinity of its own, the goddess Mellonia. Medieval Christians seem to have been quite as eager to show their appreciation of the insect. While the housefly had to be satisfied with the patronage of Beelzebub and the ant was given so obscure a patron saint as St. Saturninus, the honey-bee enjoyed the special favor of the Virgin or was even made the "*ancilla domini,*" the maid-servant of the Lord. Those who represented the divinity on earth, of course, added the honey-bee to their insignia. It appears on the crown of the Pharaohs as the symbol of Lower Egypt, on the arms of popes and on the imperial robes of the Napoleons. Among the ancients the behavior of bees was supposed to be prophetic and the insect thus naturally became associated with Apollo, the Delphic priestess, the Muses and their protegées, the poets and orators. Honey and wax were early believed to have medicinal and magical properties and were, of course, used for sacrificial purposes. Their ritual value is apparent also in the Christian cult, for honey was formerly given to babies during baptism and the tapers of our churches are supposed to be made of pure bees' wax ("*nulla lumina nisi cerea adhibeantur*").

Among the many myths that have grown up around the honey-bee, that of the "bugonia" may be considered more fully, because it shows how entomology may throw light on questions that have puzzled and distracted the learned for centuries. For nearly three thousand years people believed that the decomposing carcass of an ox or bull can produce a swarm of bees by spontaneous generation. The myth evidently started in Egypt and appears in a distorted form among the Hebrews, among whom, however, it is a dead lion in which Samson finds the honey-comb. Among the Greeks and Romans it becomes more elaborate, and Virgil, in the fourth book of the Georgics, and many other authors give precise directions for the killing and treatment of the ox if the experiment is to be successful. The medieval writers repeat what they read in the classics or invent more fantastic accounts. It was not till the eighteenth century that Réaumur showed that what had been regarded as bees issuing from the decomposed ox carcass must

have been large two-winged flies of the species now known as *Eristalis tenax,* which breed in great numbers in carrion and filth and look very much like worker bees. The history of this myth of the oxen-born bees has been more adequately discussed by a distinguished dipterist, Baron Osten Sacken. He remarks that "the principal factor underlying the whole intellectual phenomenon we are inquiring into is the well-known influence which prevails in all human matters, and this factor is *routine.*" "Thinking is difficult, and acting according to reason is irksome," said Goethe. People see and believe in what they see, and the belief easily becomes a tradition. It may be asked: If those people had that belief, why did they not try to verify it by experiment, the more so as an economical interest seemed to be connected with it? The answer is that they probably did try the experiment, and did obtain *something* that looked like a bee; but that there was a second part of the experiment, which, if they ever tried it, never succeeded, and that was, to make that bee-like something produce honey. If they did not care much about this failure, and did not prosecute the experiment any further, it is probably because, in most cases, they found that it was much easier to procure bees in the ordinary way. That such was really the kind of reasoning which prevailed in those times clearly results from the collation of the passages of ancient authors about the "*Bugonia.*"

It would seem that the strange vitality of the bugonia myth during so many centuries must have been due to some keen emotional factor or religious conviction deeper than the mere inertia of routine thinking to which Osten Sacken refers. Let us work backwards from the golden bees embroidered on the state robes of Napoleon I and supposed to symbolize his official descent from Charlemagne, who is said to have worn them on his coat of arms. It is probable that the fleurs-de-lys, which also figure on his arms and those of the later French kings are really conventionalized bees and not lilies, spear-heads or palm trees with horn or amulets attached, as some archeologists have asserted, and that Charlemagne derived his bees from one of the first kings of the Salian Franks, the father of Clovis, Childeric I, who died A. D. 481. In 1653 the tomb of this monarch was opened at Tournay, in Flanders, and found to contain a number of objects which indicated that he had been initiated into the cult of Mithra, that soldiers' religion which had been so widely diffused by the Romans over Gaul, Britain and Germany during the first centuries of our era and had come so near to supplanting Christianity. Among the objects taken from Childeric's tomb were a golden bull's head and some 300 golden bees, set with precious stones and provided with clasps which held

them to the king's mantle. Now the numerous Mithraic monuments that have been unearthed in many parts of the Roman empire show as their central figure Mithra slaying a bull surrounded by several symbolic animals, one of which is the bee. It is known also that honey was used in the initiation rites of Mithra, who was an oriental sun-god like the Hebrew Samson, the Phoenician Melkart and the Greek Hercules. From the blood of the slain bull, a symbol of the inert earth fertilized by the sun's rays, the animal world was supposed to have arisen by spontaneous generation. The bee would seem, therefore, to be one of the symbols of this renewal of life and to recall the epiphanies of many other sun and vegetation gods among the Greeks and Asiatic peoples, such as Adonis, Attis and Dionysus, or Bacchus, who as Dionysus Briseus, the "squeezer of honey-comb" was by some regarded as the god of apiculture. But the bugonia myth can be traced still further back to the Apis cult of the Egyptians. The bull Apis was believed to be an incarnation of the sun-god Osiris and to represent the renewal of life. His son Horus is another sun-god, and it is interesting to note that one of his symbols is the fleur-de-lys, which signifies resurrection. That this is the true meaning of the bugonia myth is indicated also by the magical directions given by Virgil and others for slaying the ox and caring for his carcass. The animal must be carefully chosen and in the spring, when the sun is in the sign of the bull, clubbed to death or suffocated by having the apertures of his body stuffed with rags—obvious precautions to prevent the ox's vitality from escaping so that it may be conserved for the generation of the swarm of bees. The ancients seem to have had an inkling of the parthenogenesis of the honey-bee, since many of them state that, unlike other animals, it never mates. This belief, too, served to connect the bee with the various sun and vegetation gods, all of whom, including the bull Apis, were born of virgins. Thus it will be seen that the bee became the symbol of the ever-recurring resurrection, or renewal of life in general and hence probably also of the second birth of the initiate into such cults as those of Mithra. Unfortunately there were among the ancients no entomologists to point out to the religious enthusiasts that they had mistaken a common carrion fly for the honey-bee and had therefore chosen a wrong symbol.

I have dwelt on this myth because it is such a good example of the bad observation and worse conjecture that have clouded our knowledge of the honey-bee. Even such pioneer observers as Swammerdam, Réaumur and François Huber in the seventeenth and eighteenth centuries and Dzierzon, Leuckart, von Siebold and von Buttel Reepen in more recent times have had difficulty in

clearing a path through the jungle of superstitions and speculations that have grown up around the insect during the past five thousand years. And to-day many of our scientific treatises contain vestiges of these unbridled fancies. Another obstacle to a clear understanding of the honey-bee is the very abundance of the literature. There must have been libraries devoted to it among the ancients, for even Carthage had her celebrated apiarists. Some notion of the present conditions may be gleaned from Dr. E. F. Phillips' statement that the Bureau of Entomology at Washington has a working bibliography of 20,000 titles on the honey-bee. This does not, of course, include a great number of bellettristic works like Virgil's Georgics, Maeterlinck's "Vie des Abeilles" and Evrard's "Mystère des Abeilles."

Greatest of all the sources of a misunderstanding of the honey-bee is the fact that although it is a very highly specialized and aberrant insect, it has been regarded as a paragon in the light of which the social organizations of all other insects are to be interpreted. Its evolutionary interpretation has therefore encountered the same obstacles as that of man, for the honey-bee bears much the same relation to other bees that man does to the other mammals; and just as man's obstinate anthropocentrism has retarded his understanding of his own history and nature, so the apicentrism of the observers of the honey-bee has tended to distort our knowledge, not only of other social insects but of the honey-bee itself. It is necessary, therefore, to relegate the insect to its proper place at the end of a long series of developments. I shall return to it at the end of the lecture.

As classified by the entomologists, the bees comprise about 10,000 described species and occur in all parts of the world. In Europe alone there are some 2,000 species and our North American forms, when thoroughly known, will probably be found to be even more numerous. Less than 500, or 5 per cent., of the 10,000 species are social and belong to only five genera—Trigona, Melipona, Bombus, Psythirus and Apis—the remainder being solitary forms of many genera, several of which are very large and widely distributed. For more than a century talented entomologists have studied the bees intensively but have been unable to work out any generally acceptable grouping of the various genera. Whether these insects are to be regarded as a superfamily (Apoidea), comprising several families, or as a single family (Apidæ), comprising a number of subfamilies, seems to depend on the individual investigator's more radical or more conservative frame of mind.

The bees, taken as a whole, are properly regarded merely as a group of wasps, which have become strictly vegetarian and feed

exclusively on the pollen and nectar of flowers. They are, in a word, merely flower-wasps—"Blumenwespen," as they are called by some German entomologists. A recent authority, Friese, believes that they are descended directly from at least two different ancestral groups of Sphecoid solitary wasps, one of which includes genera like Passaloecus and leads up to Prosopis and other primitive bees, while the other comprises Tachytes-like forms and leads up to the higher bees. It should be noted that a third ancestral group of Vespoids, allied to the Eumenid wasps, evidently gave rise to the Masarinæ, which are also flower-wasps and in their habits closely resemble the solitary bees.

Their very long and intimate association with the flowers has left its stamp on all the organs and habits of the bees, and botanists believe that a great many flowers have been modified in structure, arrangement, color and perfume in adaptation to the bees and for the purposes of insuring cross-pollination. Limitations of time prevent me from dwelling on the vast and fascinating subject of these relationships, though they belong to that order of interorganismal cooperation which I have called coenobiotic. Nor can I stop to dwell on our great debt to the bees for the pollination of our fruit trees and other economic plants. Something must be said, however, concerning the anthophilous adaptations of the insects themselves. It is evident that only insects with well-developed wings, with large, finely facetted eyes and well-developed antennæ, furnished with extremely delicate tactile and olfactory sense-organs, could have acquired such intimate relations to the flowers. And since the bees not only collect but transport the pollen and nectar we find some very interesting structures developed for these particular functions. Two pairs of mouth parts, the maxillæ and especially the tongue, are peculiarly modified for lapping or sucking up the nectar. In the more primitive bees that visit flowers with exposed nectaries these parts are short and much like those of the wasps, whereas in more specialized species that visit flowers with nectaries concealed in long tubes the tongue is greatly elongated. In some tropical bees the organ may be even longer than the body (Fig. 34). In order to store the nectar while it is being transported to the nest, the crop, or anterior portion of the alimentary tract, is large, bag-like and distensible and its walls are furnished with muscles which enable the bee to regurgitate its content. This is known as honey, because the nectar, during its sojourn in the crop, is mixed with a minute quantity of a ferment, or enzyme, presumably derived from the salivary glands, and undergoes a chemical change, its sucrose, or cane sugar being converted into invert sugars (levulose and dextrose).

FIG. 34
A long-tongued Neotropical bee (*Eulaema mussitans*). About twice natural size. Original.

Even more striking are the adaptations for collecting and carrying the pollen. The whole surface of the bee's body is covered with dense, erect hairs, which, unlike those of other insects, are branched, plumose, or feather-like and easily hold the pollen grains till the bee can sweep them together by combing itself with its legs (Fig. 35). Many bees thus bring the pollen together into masses moistened with a little honey and attach them to the outer surfaces of the tibiæ and metatarsi of the hind legs (Figs. 37 and 38). These parts are peculiarly broadened and provided with long hairs to form a special pollen-basket, or corbicula (Fig. 36). In other

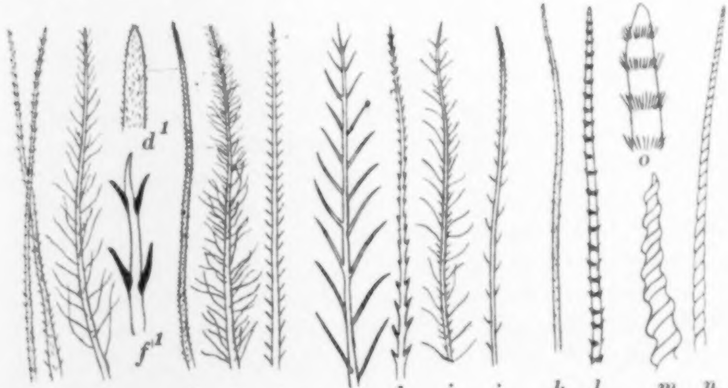

FIG. 35
Hairs of various bees. *a-f*, of bumble-bees; g-j, of *Melissodes* sp.; *k-n*, of *Megachile* sp. After John B. Smith.

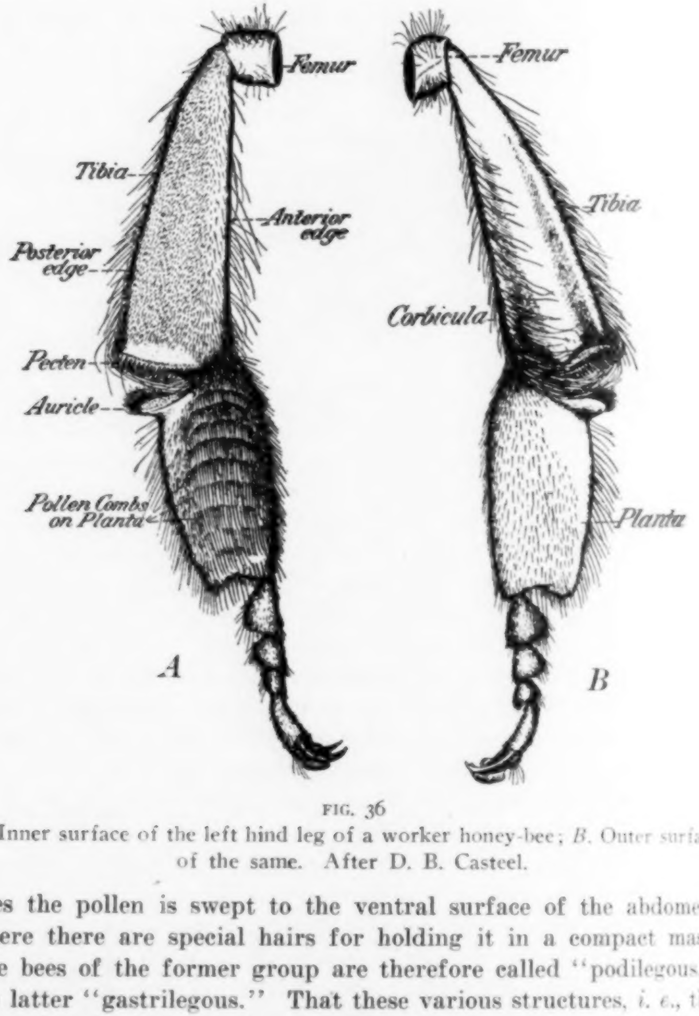

FIG. 36
A. Inner surface of the left hind leg of a worker honey-bee; *B*. Outer surface of the same. After D. B. Casteel.

bees the pollen is swept to the ventral surface of the abdomen, where there are special hairs for holding it in a compact mass. The bees of the former group are therefore called "podilegous," the latter "gastrilegous." That these various structures, *i. e.*, the general body investment of plumose hairs and the modifications of the hind legs or venter are special adaptations for pollen collection and transportation is proved by certain interesting exceptions. Thus the small bees of the very primitive genus Prosopis look very much like diminutive wasps; they have naked bodies and appendages and their hind legs are not modified. But these bees swallow the pollen as well as the honey and carry both in their crops. Then there is a long series of genera of parasitic bees which lay their eggs in the nests of the industrious species and on this account do not need any collecting or transporting apparatus. Such bees are more or less naked and their tibiæ have returned to the simple structure seen in the wasps. And, of course, since

male bees in general do not have to collect pollen we find that they, too, show considerable reduction in the hind legs as compared with the cospecific females.

There are great differences among the bees in the range of their attachment to the flowers. Some, like the honey-bee and the bumble-bees, visit all sorts of flowers and are therefore called polytropic, whereas others, the so-called oligotropic species, may confine their attentions to the flowers of a very few plants or even to those of a single species. The oligotropic are probably derived from polytropic bees which have found it advantageous to avoid competition with other species and to make their breeding season coincide with the blooming period of a single plant. A good example is one of our small black bees, *Halictoides novæ-angliæ* which at least in New England visits only the purple flowers of the pickerel weed, *Pontederia cordata.*

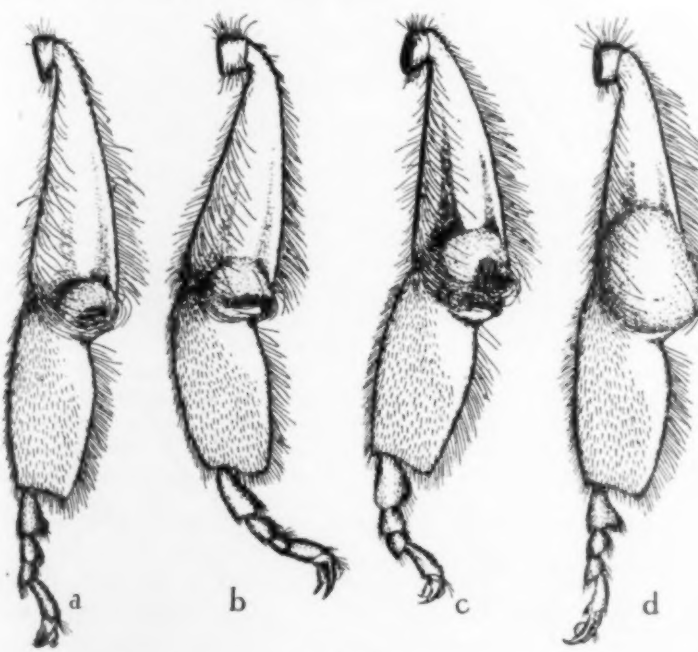

FIG. 37
Outer surfaces of left hind leg of worker bees in successive stages of pollen accumulation. *a,* from a bee just beginning to collect. The pollen mass lies at the entrance of the basket. The planta is extended, thus lowering the auricle. *b,* slightly later stage, showing increase in pollen. The planta is flexed, raising the auricle. The hairs extending outward and upward from the lateral edge of the auricle press upon the lower and outer surface of the small pollen mass, retaining and guiding it upward into the basket. *c* and *d,* slightly later stages in the successive processes by which additional pollen enters the basket. After D. B. Casteel.

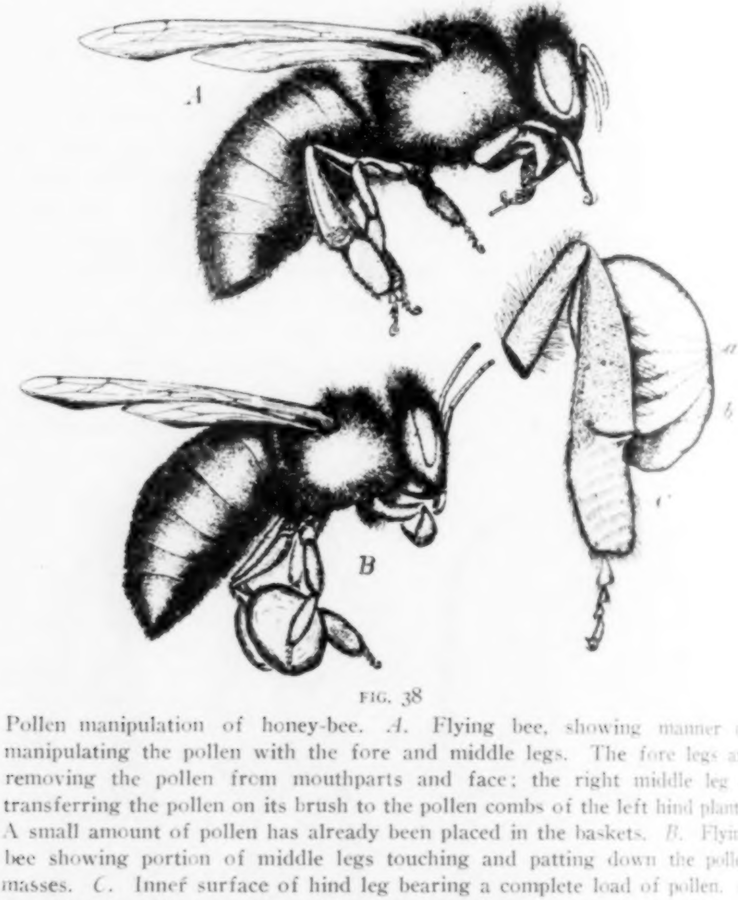

FIG. 38

Pollen manipulation of honey-bee. *A*. Flying bee, showing manner of manipulating the pollen with the fore and middle legs. The fore legs are removing the pollen from mouthparts and face; the right middle leg is transferring the pollen on its brush to the pollen combs of the left hind planta. A small amount of pollen has already been placed in the baskets. *B*. Flying bee showing portion of middle legs touching and patting down the pollen masses. *C*. Inner surface of hind leg bearing a complete load of pollen. a. Scratches in pollen mass caused by pressure of the long projecting hairs of the basket upon the pollen mass as it has been pushed up from below. b. groove in the pollen mass made by the strokes of the auricle as the mass projects outward and backward from the basket. After D. B. Casteel.

Turning now to the reproductive behavior which has led to the development of societies we find a most extraordinary parallelism between the group of bees as a whole and that of the wasps as described in my previous lecture. The progress from the solitary condition, shown in more than 95 per cent. of the species, to the conditions in the most highly socialized form, the honey-bee, is, so to speak, a repetition of the various wasp *motifs* set in a different key. Every one of the thousands of species of solitary bees has its own peculiarities of behavior, but the differences are usually so insignificant that the habits as a whole are very monotonous. With the exception of the parasitic bees, which have been secondarily evolved from non-parasitic forms, all the solitary bees make their

nests either in the ground or in the cavities of plants, in crevices of walls, etc., or construct earthen or resin cells (Fig. 39). Some species line their nest cavities with pieces of the leaves or petals of plants, with plant-hairs or particles of wood, or with films of secretion which resemble celluloid or gold-beater's skin. Most of these materials, as will be noticed, are derived from plants. The nest usually consists of several cylindrical or elliptical cells arranged in a linear series or more rarely in a compact cluster, and as soon as a cell has been completed, it is provisioned with a ball or loaf-shaped mass of pollen soaked with honey and called "bee-bread," an egg is laid on its surface and the cell is closed. We have here again the typical mass provisioning of the solitary wasps, very similar to that of the Eumeninæ, except that vegetable instead of animal substances are provided for the young. Nevertheless, the pollen and honey are ideal foods, since the former is rich in

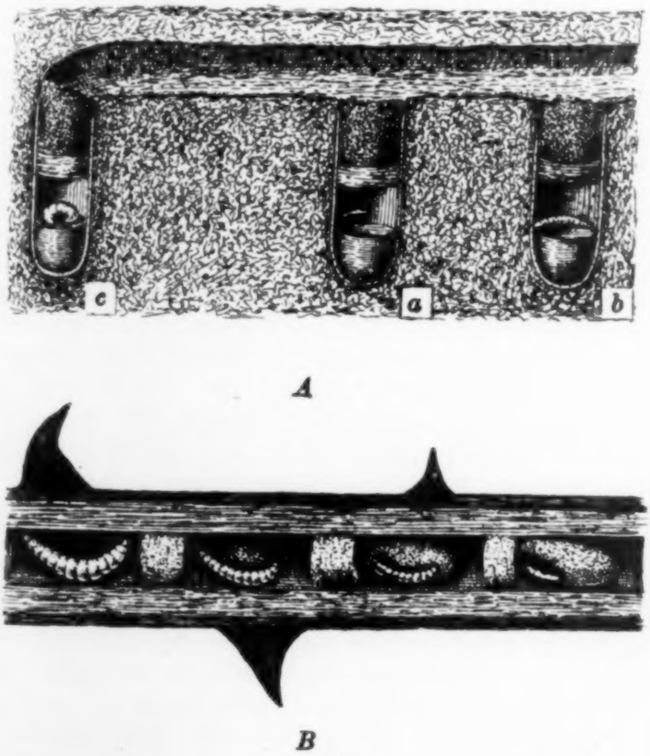

FIG. 39

Nests of Solitary bees. *A*. Nest of *Colletes succinctus* in the ground. After Valery Mayet. *a*, cell provisioned and supplied with an egg; *b*, cell with young larva; *c*, with older larva. *B*. Nest of a small carpenter bee (*Ceratina curcurbitacea*) in a hollow Rubus stem; showing egg, three larvæ of different stages and bee bread in three of the cells. After Dufour and Perris.

proteids and oils and the latter in sugar and water, and both contain sufficient amounts of various salts for the growth of the larvæ. As in the case of the solitary wasps the mother bee dies before her progeny emerge.

Just as among the solitary wasps, we often find female solitary bees nesting in close association with one another, and in some species (*Halictus longulus, Panurgus, Euglossa, Osmia vulpecula* and *parietina, Eucera longicornia*) the females, though occupying separate nests, nevertheless build a common entrance tunnel. Still there is nothing in these arrangements to indicate that they could lead to the formation of true societies. There are, however, a few cases which might be regarded as sub-social, since the mother bee survives the development of her progeny and shows more interest in their welfare than is implied by the mere mass provisioning of the cells. Two such cases are represented by the European *Halictus quadricinctus*, observed by Verhoeff, and *H. sexcinctus*, observed by Verhoeff, von Buttel Reepen and Friese. The female of the former bee digs a long vertical tunnel in the ground and at its lower end a chamber in which she constructs a number of earthen cells, arranged in the form of a rude comb. These cells, of which there may be as many as 16 to 20, are successively provisioned and closed, but the mother is long-lived, guards the nest and may even survive till the young emerge. Hence there is here an actual though apparently very brief contact of the mother with her adult offspring.

Certain peculiarities in the life-history of Halictus may be conceived to tend still further towards social development. According to our present unsatisfactory knowledge of these bees, at least some of the species have two annual generations. The spring generation consists of fecundated females that have over-wintered from the previous fall. These give rise to a summer generation consisting entirely of females. Their eggs develop parthenogenetically, but produce both males and females, forming the fall generation. The males soon die, but the fecundated females go into hibernation. As von Buttel Reepen suggests, a society might be readily established in a form like *H. quadricinctus* if the parthenogenetic generation of females were to remain with their mother and extend the parental nest. This would be essentially what we find in the lower social wasps like Polistes.

A still more interesting case has been found by Dr. Hans Brauns among the bees of the genus Allodape which belong to the gastrilegous division and are closely related to our small carpenter bees of the genus Ceratina, so abundant in hollow stems of the elder and sumach. Dr. Brauns made his observations in

South Africa, where he has been living for many years, and kindly sends me the following unpublished data for use in this lecture:

"The species of Allodape nest in the dry, hollow stems of plants, very rarely in galleries in the soil. In both cases they gnaw out cavities or occupy those already in existence. Plant stems with pithy contents, like those of Rubus, Liliaceæ, Aloe, Amaryllidaceæ, Asparagus, Acacia thorns, etc., are preferred. Three different groups of species may be distinguished according to the method employed in provisioning the young. These three groups may also prove to be useful as morphological sections of the genus, since the majority of Allodape species, especially the smaller ones, are very difficult to distinguish in the female sex. The males yield better characters, though there are few plastic characters in the genus. Most of the descriptions drawn from single captured specimens have little value. Fanatical describers, like some of your countrymen, merely make the work of the monographer more difficult or more unattractive or even well nigh impossible in a genus which is almost as monotonous as Halictus. The three different methods of provisioning which I have been able to establish are the following:

"(1) The most primitive species, observed only on a few occasions. The mother bee collects in the nest tube as much bee-bread in single loaves or packets as the larvæ will require up to the time of pupation, precisely as in other solitary bees, *e. g.*, as in Ceratina, the form most closely related to Allodape. The single food-packets are arranged one above the other in the hollow stem and each is provided with an egg. The larva holds itself to the food-packet by means of peculiar, long, segmental appendages, which I have called provisionally "pseudopodia," and consumes its single packet till it is time for pupation. The size of the packet corresponds to the size of the particular species, much as in Ceratina, and each packet nourishes only a single larva. The latter holds its appendages spread out like those of a spider and is closely attached to the packet like the larvæ of such solitary bees as Ceratina. So far there is no departure from the conditions in the solitary Apidæ. There is, however, one fundamental difference: Whereas Ceratina after provisioning and oviposition closes off each cell with a partition of gnawed plant materials and therefore makes a series of individual cells, Allodape *constructs absolutely no partitions*. The food-packets, each large enough for a *single larva* and each furnished with a *single egg*, though arranged in a linear series one behind the other in the nest tube, as in Ceratina, Osmia, etc., lie freely one on top of the other and are not separated by partitions of the materials above mentioned. The

lowermost packet is the oldest and is therefore usually found to bear a larva while each of the upper packets bears an egg. This difference, as you will admit, must be regarded as of fundamental importance. In these more primitive species the mother does not come into contact with the larva since the latter has been provided *once for all* with sufficient food to last it till it pupates, precisely as in the solitary bees and wasps. The pseudopodia can not therefore have the function of exudate organs but merely serve to attach the larva mechanically to the food-packet. This transition from isolated cells to a simple unseparated series of packets is, of course, very interesting and significant.

"(2) Rather common, small and medium-sized species. The mother bee glues a number of eggs, each by one pole and in a *half spiral row*, determined by the curvature of the tubular cavity, to the wall of the nest, usually near the middle, *i. e.*, a little above or a little below. One common species I have also seen occupying tubular cavities in the earth with a similar arrangement of the eggs. The hatching larvæ hold fast to the walls of the tube by means of their pseudopodia and *are all at the same level with their heads directed towards the entrance to the cavity*. From time to time the mother brings in a small lump of bee-bread and deposits it in the midst of the hungry heads. The larvæ therefore all eat *simultaneously of the same mass of bee-bread*. During their last moult the mature larvæ lose the pseudopodia and become pupæ, which come to lie one behind the other in the tubular nest cavity. In these species, therefore, the mother remains in continuous contact with the larvæ.

"(3) The majority of species, from those of small to those of the largest size. The mother bee lays her eggs singly and loosely on the bottom of the nest tube. In proportion to the size of the bee the eggs are very, one might say abnormally, large and seem to be laid at longer intervals. The mother bee feeds the individual larva, which *clasps the particle of bee-bread* with its two large pseudopodia so that it *has the food all to itself*. When a nest that has been occupied for some time by a mother bee, is examined, one or several larvæ, each with its own pellet of bee-bread, are found in the position I have described. Later the daughters help their mother in provisioning the larvæ. When the colony has become populous the cavity of the tube is found to be stuffed with larvæ and pupæ in all stages. The latest egg, however, almost always lies on the floor of the tube. And since the mother bees must always go to the bottom to feed the youngest larvæ, the contents of the tube are often intermingled, though the larger larvæ and the pupæ are mostly nearer the opening and therefore upper-

most. In these species, also, the larvæ lose the pseudopodia during the last moult."

Brauns's observation on Allodape are of great interest and importance because they reveal within the limits of a single genus a series of stages beginning with a mass-provisioning of the young, like that of the solitary bees and wasps, and ending with a stage of progressive provisioning. And not only has the latter led to an acquaintance of the mother with her offspring but in the third group of species described by Brauns to an affiliation of the offspring with the mother to form a cooperative family or society. It would seem that this condition must have had its inception, as Brauns suggests, in so simple a matter as the omission of the series of partitions which all other solitary bees construct between their provisioned cells. The final stage in which the individual larvæ are fed from day to day by the mother and her daughters with small pellets of food is not essentially different from what we shall find in the bumble-bees and certain ants.

Yet these rudimentary societies of certain species of Halictus and Allodape must not be regarded as the actual precursors or sources of the conditions which we observe in the three groups of social bees, namely, the Bombinæ, or bumble-bees, the Meliponinæ, or stingless bees, and the Apinæ, or honey-bees. Though these all belong to the podilegous division, no one has been able to point out their putative ancestors among existing solitary bees, and it is evident that we can neither derive them from one another nor from any single known extinct genus. Each possesses its own striking peculiarities and each is an independent branch from the ancestral stem now vaguely represented by the solitary bees. The bumble-bees are the most primitive, the honey-bees the most specialized, while the stingless bees exhibit a combination of primitive and specialized characters different from those of either of the other subfamilies. But just as all the social wasps differ from the solitary wasps in employing a peculiar nest material—paper—so the three groups of social bees differ from the solitary bees in using another peculiar nest material—wax. This material is, however, a true secretion, which arises in the form of small flakes from simple glands situated between the abdominal segments of the insects (Fig. 40). The three groups of social bees also agree in the structure of the hind tibia, the outer surface of which is not only broadened as in solitary forms but smooth and shining with recurved bristles along the edges (Fig 36). This is called the corbula and among solitary bees is known to occur only in Euglossa.

The bumble-bees represent a stage of societal development of the greatest interest to the evolutionist. Of these large insects

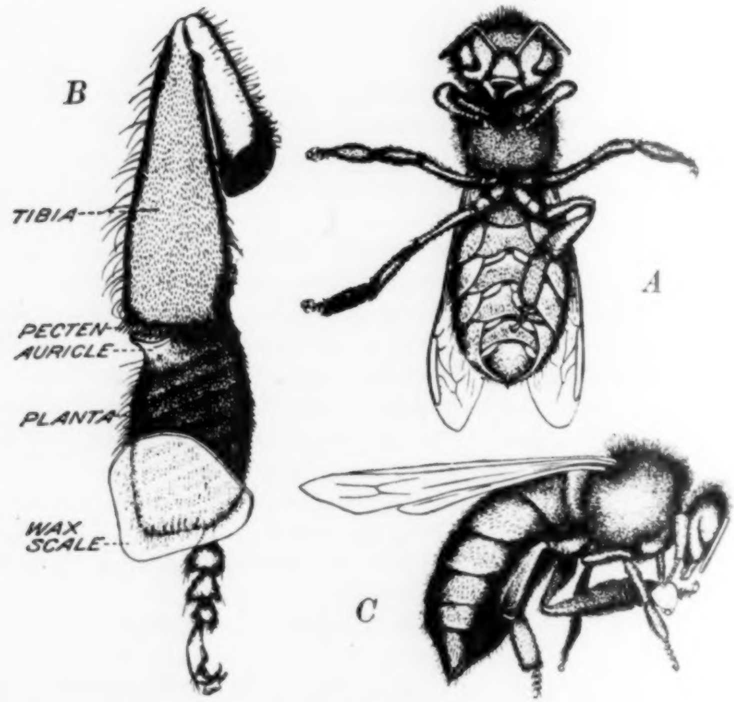

FIG. 40

A. Ventral view of worker honey-bee in the act of removing a wax-scale. *B.* Inner surface of left hind leg, showing the position of a wax-scale immediately after it has been removed from the wax pocket. The scale has been pierced by seven of the spines of the pollen combs of the first tarsal segment of the planta. *C.* Side view of a worker bee showing position of wax-scale just before it is grasped by the fore legs and mandibles. The scale is still adhering to the spines of the pollen combs. The bee is supported upon the two middle legs and a hind leg as in *A.* After D. B. Casteel.

about 200 species are known, mostly confined to Eurasia and North America. They prefer rather cool climates and several species occur in the arctic regions or at high elevations. Their habits have been carefully studied by several European entomologists, notably by Hoffer, Wagner, Lie-Petersen and Sladen, and are beginning to attract students in this country. We know very little about the species of Central and South America and the East Indies.

In temperate regions bumble-bee colonies are annual developments, like those of our northern species of Vespa and Polistes. The large fecundated female or queen overwinters precisely like the females of the solitary wasps and starts her colony in the spring. She chooses some small cavity in the ground or in a log, preferably an abandoned mouse-nest, and after lining it with pieces of grass or moss or rearranging the pieces already present, proceeds to the

important business of establishing her brood. The various stages in this behavior have been carefully observed by Sladen: "In the center of the floor of this cavity she forms a small lump of pollen-paste, consisting of pellets made of pollen moistened with honey that she has collected on the shanks (tibiæ) of her hind legs (Fig. 41*a*). These she moulds with her jaws into a compact mass, fas-

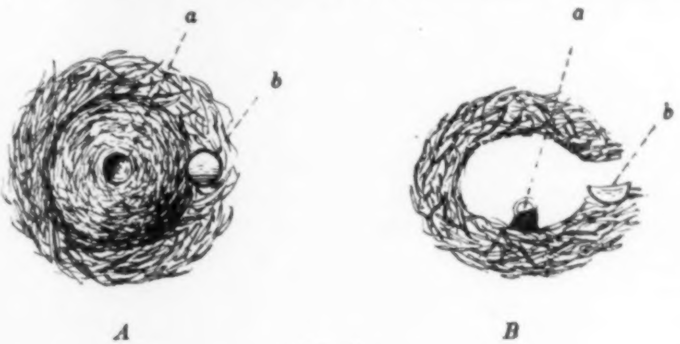

FIG. 41
Incipient nest of bumble-bee. *A*. Pollen and first eggs. *B*. Honey pot. After F. W. L. Sladen.

tening it to the floor. Upon the top of this lump she builds with her jaws a circular wall of wax, and in the little cell so formed she lays her first batch of eggs (Fig. 42*Ba*), sealing it over with wax by closing in the top of the wall with her jaws as soon as the eggs have been laid. The whole structure is about the size of a pea. . . . The queen now sits on her eggs day and night to keep them warm, only leaving them to collect food when necessary. In order to maintain animation and heat through the night and in bad weather when food can not be obtained, it is necessary for her to lay in a store of honey. She therefore sets to work to construct a large waxen pot to hold the honey (Fig. 41*b*, 43, 44). This pot is built in the entrance passage of the nest, just before it opens into the cavity containing the pollen and eggs, and is consequently detached from it. The completed honey pot is large and approximately globular, and is capable of holding nearly a thimbleful of honey."

Up to this point the behavior of the queen is much like that of the solitary bee which makes and closes her cell after providing it with provisions and an egg, but a significant change now supervenes. The eggs hatch after about four days and the further events are described by Sladen as follows: "The larvæ devour the pollen which forms their bed, and also fresh pollen which is added and plastered onto the lump by the queen. The queen also feeds them with a liquid mixture of honey and pollen, which she prepares by

swallowing some honey and then returning it to her mouth to be mixed with pollen, which she nibbles from the lump and chews in her mandibles, the mixture being swallowed and churned in the honey-sac. To feed the larvæ the queen makes a small hole with her mandibles in the skin of wax that covers them, and injects through her mouth a little of the mixture among the larvæ which devour it greedily. Her abdomen contracts suddenly as she injects the food, and as soon as she has given it she rapidly closes up the hole with the mandibles. While the larvæ remain small they are fed collectively, but when they grow large each one receives a separate injection.''

Here we have a beautiful transition from mass to progressive provisioning. Sladen then describes the further development of the brood: ''As the larvæ grow the queen adds wax to their covering, so that they remain hidden (Fig. 42 *BEb*). When they are about five days old the lump containing them, which has hitherto been expanding slowly, begins to enlarge rapidly, and swellings, indicating the position of each larva, begin to appear in it. Two days later, that is, on the eleventh day after the eggs were laid, the larvæ are full-grown, and each one then spins around itself an oval cocoon, which is thin and papery but tough (Fig. 42 *Cc*). The queen now clears away most of the brown wax covering, revealing the cocoons, which are pale yellow. These first cocoons number from seven to sixteen, according to the species and the prolificness of the queen. They are not piled one on another, but stand side by side, and they adhere to one another very closely.

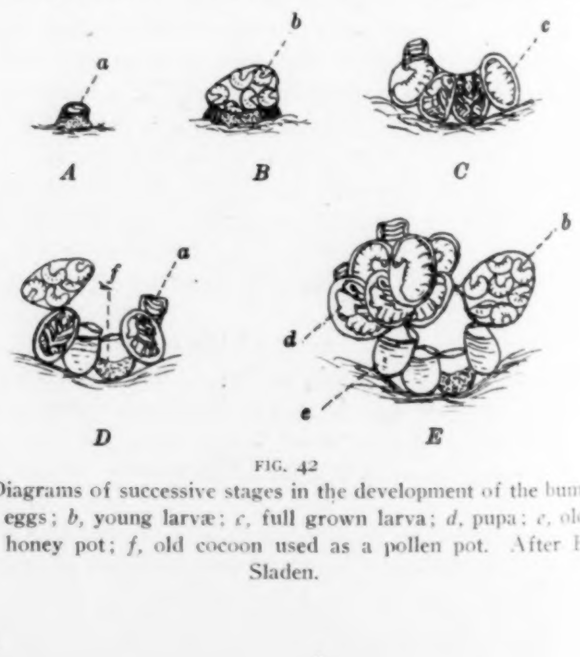

FIG. 42

A to *E*. Diagrams of successive stages in the development of the bumble-bee's brood. *a*, eggs; *b*, young larvæ; *c*, full grown larva; *d*, pupa; *e*, old cocoon used as a honey pot; *f*, old cocoon used as a pollen pot. After F. W. L. Sladen.

FIG. 43
Incipient nest of *Bombus terrestris*, showing honey-pot and mass of wax enclosing young brood and grooved for the accommodation of the body of the queen while incubating. After F. W. L. Sladen.

FIG. 44
Same as Fig. 43, showing the queen *Bombus terrestris* lying in the groove and incubating the young brood. After F. W. L. Sladen.

so that they seem welded into a compact mass. They do not, however, form a flat-topped cluster, but the cocoons at the sides are higher than those in the middle, so that a groove is formed; this groove is curved downwards at its ends (Fig. 43), and in it the queen sits, pressing her body close to the cocoons and stretching her abdomen to about double its usual length so that it will cover as many cocoons as possible; at the same time her outstretched legs clasp the raised cocoons at the sides (Fig. 44). In this attitude she now spends most of her time, sometimes remaining for half-an-hour or more almost motionless save for the rhythmic expansion and contraction of her enormously distended abdomen, for nothing is now needed but continual warmth to bring out her first brood of workers. In every nest that I have examined the direction of the groove is from the entrance or honey-pot to the back of the nest, never from side to side. By means of this arrangement the queen, sitting in her groove facing the honey-pot—this seems to be her favorite position, though sometimes she reverses it—is able to sip her honey without turning her body, and at the same time she is in an excellent position for guarding the entrance from intruders."

The eggs laid by the queen during the early part of the summer are fertilized and therefore produce females, but the larvæ, owing to the peculiar way they are reared, secure unequal quantities of nutriment and therefore vary considerably in size, though

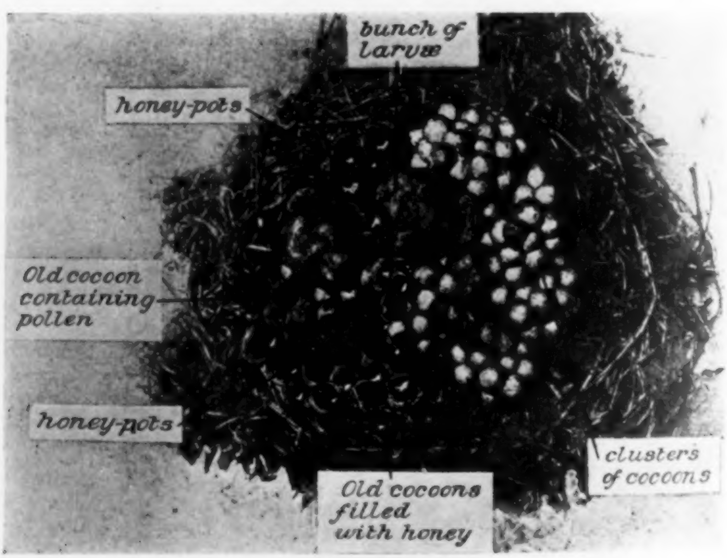

FIG. 45
Comb of *Bombus lapidarius*, showing clusters of worker cocoons, masses of enclosed larvæ, half-full honey-pots and pollen pot. After F. W. L. Sladen.

they are all smaller than their mother. Individuals scarcely larger than house-flies are sometimes produced, especially in very young colonies. All of these individuals have been called workers, although they have essentially the same structure as the queen. They are assisted in emerging from their cocoons by their mother or sisters and forthwith take up the work of collecting pollen and nectar and of enlarging the colony. The queen now remains in the nest and devotes herself to laying eggs, while the nest is protected, new cells are built and the additional broods of larvæ are fed by the workers. They also construct honey-pots and special receptacles for pollen or store these substances in cocoons from which workers have emerged (Fig. 45). Later eggs are also laid by the workers but being unfertilized develop into males. As the colony grows and becomes more prosperous, some of the larvæ derived from fertilized eggs laid by the queen are abundantly fed and develop into queens. Like the queens of the social wasps, these do not emerge from their cocoons till the late summer, and like the queen wasps, they disperse, after mating with the males, and alone of all the colony survive the winter to start new colonies the following spring. In South America, where, according to von Ihering, bumble-bee colonies are perennial, new nests are formed by swarming as among the social wasps of the same region. Bumble-bee colonies are, as a rule, not very populous, 500 individuals constituting an unusually large society. In many cases there are scarcely more than 100 to 200.

I have called attention to the fact that the workers are precisely like the queens, or fertile females, except that they have been more or less inadequately fed during their larval stages and are therefore smaller. They are the result of a high reproductive activity on the part of the queen under unfavorable trophic conditions that do not permit the offspring to attain their full stature. In certain species that live permanently under even more unfavorable conditions, like those in the arctic regions, the worker caste is completely or almost completely suppressed. During 20 years of residence in Tromsö, Norway, Sparre Schneider failed to find a single worker of *Bombus kirbyellus*, and those of *B. hyperboreus* were extremely rare. Probably the queens of these species are able to rear only a few offspring and these are all or nearly all males and queens, though, during the short arctic summer, at least in Finland and Lapland, the mother insects work late into the nights. But the worker caste may also disappear as a result of the opposite conditions, that is, an abundance of food. We found this to be the case with the workerless parasitic wasps, *Vespa arctica* and *austriaca*. In north temperate regions the genus Bombus has given rise to a

number of parasitic species, which have been included in a separate genus, Psithyrus. These bees are very much like Bombus, in the nests of which they live, but just as in the two species of Vespa and for the same reasons, their worker caste has been suppressed.

The foregoing account shows that the bumble-bees are very primitive and represent an interesting transition from the solitary to the social forms, since the queen while establishing her colony behaves at first like a solitary bee but later gradually passes over to a stage of progressive provisioning and affiliation of her offspring and thus forms a true society. The cells are also essentially like those of solitary bees, except that they are made of wax, but even in the secretion of the wax the bumble-bees represent the primitive conditions, as compared with the stingless bees and honey-bees, since the substance is exuded between both the dorsal and ventral segments of the abdomen.

THE POLYNESIANS: CAUCASIANS OF THE PACIFIC

By CLIFFORD E. GATES
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IN the oceanic islands of the Pacific three different peoples occur, who have been called Melanesians, Micronesians and Polynesians. These form very distinct divisions. The Melanesians are physically negroid, nearly black with crisp, curly hair, flat noses and thick lips. Although nothing is known of their origin, it is supposed that they came from Africa and were the earliest occupants of the oceanic world. They now occupy the western portion of the Pacific islands south of the equator including Fiji, the New Hebrides, the Solomon group and the Bismarck Archipelago.

The Micronesians are of Malay stock much modified by Melanesian, Micronesian and even Chinese and Japanese crossings. They are short, often stunted in form, and have a dark brown complexion. They inhabit the western portion of the Pacific islands north of the equator, including the Marshall Islands, the Gilbert Islands, the Caroline Islands and Guam.

The Polynesians represent a branch of the Caucasian race who migrated in a remote period, possibly in the Neolithic age, from the Asiatic mainland. They have a distinct European cast of feature, have a light brown or olive complexion, and are the physical superiors even of Europeans. They inhabit all the eastern group of islands both north and south of the equator, including the Hawaiian, Marquesan, Society, Cook, Tonga and Samoan Islands.

The Micronesians, few in number and inhabiting a relatively small area of Oceanica, have been of little interest to other peoples; the Melanesians, black and savage, with a history of horror after horror, have been repellent to explorers and remain in a darkness comparable to the darkness of central Africa. But the Polynesians have cast a charm over the civilized world. They are perhaps the handsomest people extant. The men average six feet in height, are strongly muscled, free from fat, swift in action, graceful in repose; the women are often of rare beauty, with regular features and wondrous large, dark eyes. In character they are exceedingly merry, gentle, courteous and hospitable. Unless mistreated or under some misapprehension they have been almost universally friendly

to the white man; the stranger coming to their shores and passing through their villages ever and anon receives the greeting "aloha," and his departure is often the cause of sadness or weeping on the part of the islanders who may have known him at most but a few days. When Robert Louis Stevenson was about to leave the Marquesas—islands owned by France—Stanislao Moanitini, chief of Akaui, sadly addressed him with these words: "Ah vous devriez rester ici, mon cher ami. Vous êtes les gens qu'il faut pour les Kanaques; vous êtes doux, vous et votre famille; vous seriez obéis dans toutes les îles."

Nowhere does any people possess a deeper passion for color; wreaths or "leis" of flowers have always been a part of their everyday attire. Their personal cleanliness is remarkable. For them no day would be complete without a bath in one of their beautiful streams or lakes followed by an anointing of the entire body with a fragrant oil.

With these people cultured Europeans have not hesitated to form marriages, to live among them, sensitive natures have counted the world well lost, and about them has grown up a romance of story and song that has caught the interest of the civilized world. There is a saying that he who has seen Tahiti will never wish to leave it.

Their history prior to the discovery of their islands by Europeans has been learned partly through study of their characteristics, partly through study of their language, but principally through their traditions and legends. Though many examples of their rude hieroglyphics or picture symbols have been found, little has been learned from this source. The appearance and characteristics of the people point at once to a Caucasian lineage. The roots of their language point to the same conclusion. This being so, they could have come only from Asia. All their legends point to the west as the cradle of the race, and their dead are supposed to go to their future life west—naturally back to the *home* of the race. But supposing they did come from Asia, how did they ever reach Samoa and Tahiti and Hawaii? Hawaii is over 4,000 miles from Asia and only 2,000 from San Francisco. How could these people traverse two thirds of the Pacific in their canoes? Doubtless they came from island to island through the Malay Archipelago until they reached Samoa, but from there they had 2,000 miles of open ocean to traverse to reach Hawaii. How was it possible to accomplish this sail from the west when the prevailing winds and currents were from the northeast? The answer to this question lies in the character of the people. There is evidence that in the past they were the most daring and skilled navigators the world has

ever known. They built two-decked canoes of plank large enough to carry big stores of food and water and even livestock. They possessed a knowledge of the stars and steered their course by them. That they must have come this way is further evidenced by the fact that an intelligent Polynesian of Hawaii can understand almost everything that a Samoan says even though the islands lie so far apart, and, except for the several waves of colonization, have had no intercourse with each other prior to the arrival of the European. Nearly all the ethnologists are agreed upon this theory of the origin of the race. At the present time further investigations are being made by the Bishop Museum and Yale University. Their work is only half completed, but already they have collected a vast amount of information which it is believed will still further corroborate the accepted theory.

Arrived at the islands the Polynesians found conditions admirably suited to their needs. The soil, usually being of volcanic origin, was fertile and covered with a rich vegetation, including the taro, the bread-fruit, the sweet potato, the yam and the banana. The waters about the islands abound in fish, and though no edible animals appear to have been indigenous, the early settlers brought with them pigs which flourished in both a wild and domestic state and have always been highly regarded as a food by the natives.

For many centuries they led a savage but contented existence here, completely shut off from the rest of the world. Happy would they have been if they could have remained in this seclusion! Early Spanish navigators touched at some of the smaller islands and by the eighteenth century all of the main groups were known. The Hawaiian Islands were the last to be discovered, being unknown until an English navigator, Captain James Cook, landed there in 1778.

At the time of discovery the different groups of islands were in various stages of advancement, the Samoans being the most civilized and the Marquesans the most savage. All of them were living in a feudal state, similar to that which prevailed in Europe in medieval times. The chiefs owned all the land and parcelled it out among their followers, who however were not bound to the land but if dissatisfied could transfer their allegiance to some other chieftain. For many years there had been waging almost continual internecine wars which must have limited the population even before discovery.

Since the coming of the European many changes have taken place in government, mode of living and religion. The islands are no longer independent. The Marquesan and Society Islands belong to France; the Cook and Tonga Islands belong to Great

Britain; the Hawaiian Islands and part of Samoa belong to the United States. The people have largely abandoned their ancient manner of living and adopted that of the European. One of their most peculiar systems was that of the tabu. The tabu was a prohibition of certain articles or certain acts and was religious in character. Anyone who violated a tabu was supposed to be visited by a certain malady and, unless the proper remedial measures were taken, in three days' time to die. Anyone could tabu anything that belonged to him, but there were a great many tabus of universal application. The following are examples: men and women were compelled to eat in separate houses, and women could not cook over a fire built by a man. Women were not allowed to eat certain food such as bananas, cocoanuts and pork. Women could not enter any canoe, but if they desired to cross any river or lake or reach a ship had to swim. A commoner was prohibited from crossing the shadow of a chief. At certain tabu periods no sound could be heard, no fire could be lighted, even the dogs were muzzled and fowls tied up. For various reasons the system is now overthrown.

The simple dress of the people, which consisted for the men of a loin cloth, for the women of a short girdle of leaves, has been changed for the more elaborate dress of the European. The native houses made of bamboo poles and thatch have given place to houses of wood. Even the occupations have changed. Formerly the native did little work aside from picking and cooking his food, spearing fish and making his simple dress and implements. Now many products are raised for export, the cultivation of sugar especially having become the main industry of most of the islands. The native religion, with its many gods, its prayers and its songs, has yielded to Christianity, the islanders accepting the new religion en masse. Doubtless the acceptance in many cases has been largely a matter of form, for the inhabitants in times of trouble still secretly address prayers to their ancient gods.

Since the coming of the foreigner the Polynesians, despite their wonderful physique, have alarmingly decreased in numbers. Captain Cook estimated the population of the Hawaiian Islands at 420,000; to-day there are only 24,000 Hawaiians of pure blood. The Tahitians numbered 150,000 in 1774, fell to 17,000 in 1880 and to 10,300 in 1899. During the last two decades of the nineteenth century the decrease has been in Tonga from 30,000 to 17,500; in the Cook group from 11,500 to 8,400; in Manakini from 1,600 to 1,000; and in Easter Island from 600 to 100. In the valley of Typee in the Marquesas, where Herman Melville was so kindly treated, from a tribe which formerly boasted 4,000 fighting men only a dozen wretches have survived.

Such a decrease can be only partly accounted for by the wars, massacres and raiding for the South American and Australian slave trade before this traffic was stopped. A more important cause is the introduction of diseases by foreigners. Sickness was almost unknown to the Polynesians prior to the coming of the foreigners, and consequently they lacked the toxin in their blood which renders other peoples partially immune. A mild disease has been known to carry them off by the thousands; a single epidemic of measles once destroyed a tenth of all the natives of the Hawaiian Islands. Their swift change of habits has also rendered them the victims of many plagues. The Polynesian is amphibious by nature and as much at home in the water as out of it. In his scant native costume he would quickly dry off upon emerging from the water and be no worse off for his bath. Having adopted the trousers and shirt of the European he still goes into the water with his clothes on, insisting that if clothes are good they are good *all* the time. The clothes remain wet after he emerges and bring a heavy toll upon life in the forms of pneumonia and tuberculosis. The replacement of the native hut by the wooden house has exposed the native to the same plagues. The hut, made of thatch, was always well ventilated because of the looseness of its structure; the wooden house, of which the native persistently refuses to open the windows at night, is close and stuffy. The prohibition of the joyous native pastimes by over-zealous missionary endeavor, together with the lugubriousness of some of the things taught him, has depressed the native, rendering him an easier prey to the ravages of disease. The introduction of rum and opium has been a calamity to him, weakening and degrading him more than "firewater" has degraded the American Indian.

From every point of view the coming of the foreigner has been an immeasurable curse to the Polynesian. Left to themselves the Islanders could be living to-day in a paradise unvisited by the plagues, pestilence and calamities that attack mankind now the world over. Before the visitation of the European and the Asiatic their flowery isles set in the midst of dark blue seas were far removed from every beast of prey, every poisonous serpent, every malady rising from the congested slums of earth. The gentle people led a carefree existence, spending much of their time swimming, riding the surf, playing at their sports of wrestling, boxing and football, dancing their expressive folk-dances of love and goodwill.

How changed is it all now! From the east and from the west have come calamities. The mosquito, the rat, the mongoose have arrived; though there are still no snakes, some fool will doubtless

soon import a couple of rattlers. The crews of the ships brought syphilis, which among a people with loose ties of marriage was bound to rage terribly; the Chinese brought leprosy, a disease unknown in the islands prior to 1848, but now there are nearly a thousand victims of this terrible plague segregated on the island of Molokai in the Hawaiian group. The changed conditions of living have resulted in a holocaust of death from pneumonia and tuberculosis, while measles and smallpox have done their worst among a people unable to withstand them. The Polynesian is perishing. Stopped are the games and the hulahula dances, forgotten are the songs of the fathers. Yet a little while and the rippling flow of his language, more like music than like speech, will have vanished from the earth; soon the very "aloha" will be heard no more. The Polynesian understands his fate. With a smile half sad, half hopeless, he looks forward to the day when he will be but a memory among the race of men.

THE SCIENTIFIC IMAGINATION[1]

By Dr. WALTER LIBBY

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IN books and articles touching on the psychology and logic of research, a certain confusion has frequently arisen from the use of terms like *intuition, illumination,* and *inspiration,* which seem almost to defy definition, as well as from an unwarranted use of terms like *imagination* and *conception*, regarding the denotation of which there is some approach to harmony among the recognized exponents of mental science.

Among the philosophers, Wundt, Bergson and James, for example, acknowledge—each in his own way, to be sure—a close relationship between the imagination and the memory. Both of these mental processes admit of analysis into simple sensory elements. Reproductive imagination differs indeed from memory only in so far as it is unaccompanied by a sense of repetition. The productive, or creative, imagination, though it differs from the reproductive in the freedom with which it manipulates and rehandles sensory data, is nevertheless as dependent as it on the materials furnished by the eye, ear and other sense organs. We may rearrange and recombine the data supplied by sensation and retained in consciousness; we can create nothing absolutely new.

Nearly all of the chapter on imagination in James's *Principles of Psychology* would be equally relevant in a discussion of the memory. The point of view of this eminent philosopher and psychologist is so opposed to the views of writers like Tyndall and Pearson, who are inclined to identify the scientific imagination with creative thought in general (which it is our purpose to analyse), that it seems worth while to examine in some detail the phenomena of retention and recall, and, by differentiating one type of memory from another, obtain a clue to the various types of imagination in the strictest sense of that term.

Cases of remarkable powers of visual recall have been put on record by James. One of these he quotes:

[1] This is the first of a series of lectures on the "Psychology and Logic of Research," given before the Industrial Fellows of the Mellon Institute of Industrial Research of the University of Pittsburgh, February 14—May 2, 1922.

The more I learn by heart the more clearly do I see images of my pages. Even before I can recite the lines I see them so that I could give them very slowly word for word, but my mind is so occupied in looking at my printed image that I have no idea of what I am saying, of the sense of it, etc. When I first found myself doing this I used to think it was merely because I knew the lines imperfectly; but I have quite convinced myself that I really do see an image. The strongest proof that such is really the fact is, I think, the following:

I can look down the mentally seen page and see the words that commence all the lines, and from any one of these words I can continue the line. I find this much easier to do if the words begin in a straight line than if there are breaks. Example:

Étant fait ....

Tous ....

A des ....

Que fit ....

Cêres ....

    Avec ....

Un fleur..

    Comme ....

(*La Fontaine, 8.* iv.)

In an experimental study undertaken by the writer a group of ten college students were asked to memorize words and sentences in Italian, a language which none of them had studied before, and of which the experimenter was also fairly ignorant. Each of the eight exercises, employed within the space of two months, consisted of ten detached words and of about fifty words connected in sentences. The procedure was to place typewritten sheets of the words and sentences, with their translation, before the students for twenty minutes. The sheets were then collected and all copies and notes made during the study period were destroyed. Forty-eight hours later the members of the group were asked to write down all the words which could still be recalled. In the third exercise of this sort one student succeeded in reproducing correctly nine out of the ten detached words and all of the words in the sentences. The spelling, the punctuation, and even the use of accents were almost perfect. This student was a well-marked type of motor memory. She found it impossible to memorize anything effectively without writing it down. To hold a pencil in the writing position aided her to some extent to fix in memory an ordered statement of ideas. When she had tried to learn the Italian words and sentences by visualization, they seemed quite strange to her after the lapse of forty-eight hours; but, when she had copied them down, they were as old friends.

In the seventh exercise a second student succeeded in recalling the ten detached words with one mistake in spelling and, with remarkable fidelity, a song of eleven lines from an Italian opera.

He relied not on motor or visual, but on auditory imagery. He insisted at the beginning of the experiment on having the words and sentences read aloud. Later he was able, so he said, to surmise the sound of them. His mistakes corroborate his introspection concerning his type of memory. His spelling, punctuation and use of accents were less accurate than the first student's. He was able to give only the first syllable of a five-syllable word which was indistinctly pronounced by his rather incompetent instructor. The spelling "luto" for "lutto" was probably also due to the experimenter's defective pronunciation of Italian. In one line of the song the student elided two words by doubling the initial letter of the second word, but without deteriment to the rhythm. In this same exercise a third member of the group was able to recall only fourteen words out of sixty-four. His impression that his mind is of the visual type is supported by the fact that all of the words definitely remembered occur in conspicuous positions in the exercise —the first line of a stanza, the end of a line, the beginning and the end of the list of words, etc.

If the claim is put forward that great scientific discoverers have been gifted with particularly vivid imagery, we must bear in mind the actual achievements of young people of college age submitted to definite tests. In this chance group of ten students, one, as we have seen, relying on auditory imagery, was able to recall sixty-four words out of sixty-four, while another, by means of kinæsthetic imagery recalled sixty-three words out of sixty-four. Remarkable as their performances were, these students were surpassed in the total experiment by a student who was conscious (as many of us must be even in such a simple experience as holding a telephone number in consciousness for a few moments) of relying on both auditory and visual imagery.

The address of the Irish physicist Tyndall on the "Scientific Use of the Imagination," delivered before the British Association in 1870, gives evidence of the functioning of his own imagination, and raises a number of questions in reference to the use of the imagination in scientific research. He is of the opinion that in explaining sensible phenomena we habitually form mental images of the ultra-sensible. He holds that the action of the investigator is periodic, and that the emotions play no inconsiderable part in the intellectual life. Tyndall quotes Sir Benjamin Brodie as stating that the imagination is both the source of poetic genius and the instrument of discovery in science. When, however, Tyndall says that, with experiment and accurate observation to work upon, imagination becomes the architect of the theories of physical science, he seems to pass from the consideration of imagination in the strict sense of the term to the consideration of the speculative

process involved in the setting up of hypotheses; and, when he claims that without the exercise of the imagination the conception of force would vanish from our universe and that causal relations would disappear, his enthusiasm for his theme has apparently rendered him oblivious of the distinctions between mental processes. "There is," he proceeds, "in the human intellect a power of expansion—I might almost call it a power of creation—which is brought into play by the simple brooding upon facts." After this sample of amateur psychology one is not surprised to hear the physicist speaking of a composite and creative power in which reason and imagination are united. Having confused the imagination with the reason, he invents a *tertium quid* that includes them both. The example of scientific thought which he gives, concerning the process of developing analogies between the wavelets on the surface of a pond, sound waves in water or air, and light waves in the ether, does not further the differentiation of the imagination and the reason. He regards as a product of the imagination the inference that the people by whom we are surrounded are possessed of reason because they behave as if they were reasonable. For him the world of sense itself, the phenomenal world of the physicist, is largely the outcome of things intellectually discerned, and is, therefore, dependent on the imagination. In short Tyndall imparts to the term *imagination* the maximum extension and the minimum intension.

Francis Galton's essay on *Mental Imagery*, 1881, provides an antidote for the extreme views of Tyndall. In this essay Galton expresses the conviction that scientists as a class are not good visualizers. When he questioned his friends of the scientific world, including Fellows of the Royal Society and members of the French Institute, he was amazed to find that few of them could picture to themselves things recently seen, such as the breakfast-table at which each had sat a few hours previously. When, however, Galton addressed himself to persons whom he met in general society, he obtained results altogether different. Girls, boys, women, many men, could recall sights like the morning's breakfast-table with photographic vividness and in their appropriate coloring and illumination. The power to visualize is more marked in the female sex than in the male and is somewhat more active in adolescent boys than in men. A study of the drawings of the Bushmen of South Africa and of the remains of prehistoric art indicates that the visual imagery of primitive man may be of an almost hallucinatory vividness.

Convinced, by his systematic investigation of the comparative dearth of visual imagery among men of science, Galton arrives at

the conclusion that habits of highly generalized and abstract thought, the pursuit of language and book learning, are antagonistic to the faculty of perceiving mental pictures. He admits, however, that there are instances in which persons see mentally in print every word uttered in a conversation or an address, and that the highest minds are probably those in which visualization is not lost but is held as a rule in abeyance, ready for use on suitable occasions. In fact, in later studies he records the remarkable visualizing powers of men like Professor Schuster, Flinders, Petrie, and the Rev. George Henslow, botanist. Mr. Henslow recognized that visual images, which he could summon at will, differed from the original perceptions, and that they were dynamic, undergoing changes, in many cases due to a suggestiveness, in the images, of something else. At times the images oscillated or rotated in a perplexing manner.

Karl Pearson in "The Grammar of Science," 1911, resembles Tyndall rather than Galton and James as regards the scope and range he ascribes to the activity of the imagination. According to Pearson the discovery of law is the peculiar function of the creative imagination. He declares that the man with no imagination may collect facts, but that he can not make great discoveries. After an elaborate classification of such facts has been made and their relations and sequences carefully traced, the next stage in the process of scientific investigation is the exercise of the imagination. Pearson, however, insists that it is the *disciplined* imagination (comparable, no doubt, with Tyndall's composite and creative power in which reason and imagination are united) that has been at the bottom of all great scientific discoveries. He also admits that the *classification* of facts is often largely guided by the imagination as well as by the reason. At the same time he maintains that all great scientists have, in a certain sense, been great artists, and by describing a work of art as concentrating into a simple formula a wide range of human emotions and feelings, he attempts to bring the products of artistic creation into line with scientific laws. It is evident that Pearson, while emphasizing the importance in research of the creative imagination, has not contributed substantially to its analysis and differentiation.

Reserving for later consideration the complex mental processes so boldly broached by Tyndall and Pearson, let us glance, in the spirit of Galton and James, at some of the evidence concerning the employment of imagery by the scientific discoverer.

Dalton seems to have relied on visual imagery; as has been remarked by others, his mind was of a corpuscular turn. In the early stages of his meteorological work he thought of aqueous vapor as made up of minute droplets diffused among the gases of the at-

mosphere. To the particles of these gases he ascribed definite form, and represented by diagram his idea of the constitution of the air. About 1803 Dalton began to picture atoms as of different sizes. He formed visual images of molecules of nitric oxide and nitrous oxide, of carbon monoxide and carbon dioxide, of ethylene and ethane. In his laboratory note-book during the autumn of 1803 he made entry of his symbols for hydrogen (○), oxygen (⊙), nitrogen (⦶), carbon (●), sulphur (⊕), and several of their compounds, as (⊙●), (⦶⊙), (⊙●⊙), (⦶⊙⦶), etc. Dalton could not accept with equanimity the less graphic method of representing chemical elements and compounds. As late as 1837 he wrote: "Berzelius's symbols are horrifying: a young student in chemistry might as soon learn Hebrew as make himself acquainted with them. They appear like a chaos of atoms . . . . and to equally perplex the adepts of science, to discourage the learner, as well as to cloud the beauty and simplicity of the Atomic Theory." Would the development of modern chemistry have proceeded more rapidly if the symbols of Dalton, which appeal to the imaginative thinker, had triumphed over the symbols of Berzelius, which appeal to the conceptual thinker?

Kekulé has left an intimate[2] record, worth reproducing *in extenso*, of his own experience as a scientific discoverer.

> Genius has been spoken of, and the Benzene Theory has been designated a work of genius. I have often asked myself what, exactly, is genius, in what does it consist? It is said that genius recognizes the truth without knowing the proof of it. I do not doubt that from the most remote times this idea has been entertained. "Would Pythagoras have sacrificed a hecatomb if he had not known his famous proposition till he found proof?"
>
> It is also said that genius thinks by leaps and bounds. Gentlemen, the waking mind does not so think. That is not granted to it. Perhaps it would be of interest to you if I should place before you some highly indiscreet statements as to how I arrived at certain ideas of mine. During my stay in London, I lived for a long time in Clapham Road in the vicinity of the Common. My evenings, however, I spent with my friend Hugo Müller at Islington at the opposite end of the metropolis. We used to talk of all sorts of things, mostly, however, of our beloved chemistry. One beautiful summer evening I was riding on the last omnibus through the deserted streets usually so filled with life. I rode as usual on the outside of the omnibus. I fell into a revery. Atoms flitted before my eyes. I had always seen them in movement, these little beings, but I had never before succeeded in perceiving their manner of moving. That evening, however, I saw that frequently two smaller atoms were coupled together, that larger ones seized the two smaller ones, that still larger ones held fast three and even four of the smaller ones and that all whirled around in a bewildering dance. I saw how the larger atoms formed a row and one dragged along still smaller ones at the ends of the chain. I saw what Kopp, my revered teacher and friend, describes so charmingly in his

[2] *Berichte der deutschen chemischen Gesellschaft*, 1890, pages 1305-1307.

"Molecularwelt"; but I saw it long before him. The cry of the guard, "Clapham Road," waked me from my revery; but I spent a part of the night writing down sketches of these dream pictures. Thus arose the structural theory.

It was very much the same with the Benzene Theory. During my stay in Ghent, Belgium, I occupied pleasant bachelor quarters in the main street. My study, however, was in a narrow alleyway and had during the day time no light. For a chemist who spends the hours of daylight in the laboratory this was no disadvantage. I was sitting there engaged in writing my text-book; but it wasn't going very well; my mind was on other things. I turned my chair toward the fireplace and sank into a doze. Again the atoms were flitting before my eyes. Smaller groups now kept modestly in the background. My mind's eye, sharpened by repeated visions of a similar sort, now distinguished larger structures of varying forms. Long rows frequently close together, all, in movement, winding and turning like serpents! And see! What was that? One of the serpents seized its own tail and the form whirled mockingly before my eyes. I came awake like a flash of lightning. This time also I spent the remainder of the night working out the consequences of the hypothesis. If we learn to dream, gentlemen, then we shall perhaps find truth—

"To him who forgoes thought,
Truth seems to come unsought;
He gets it without labor."—

We must take care, however, not to publish our dreams before submitting them to proof by the waking mind. "Countless germs of mental life fill the realm of space but only in a few rare minds do they find soil for their development; in them the idea, of which no one knows whence it came, lives as an active process." As I have told you before, at certain times certain ideas are in the air. We hear now from Liebig that the germs of ideas are like the spores of bacilli which fill the atmosphere. Why did the germs of the Structural and Benzene ideas, which have been in the air for a period of twenty-five years, find a soil particularly favorable to their development in my head?

Kekulé thought that the answer to his own question lay partly in the effect of his early study of architecture, which had imparted to his mind an irresistible need of sensory presentation. He could not rest satisfied with an explanation of chemical phenomena unless he could support it by means of definite visual imagery.

Kekulé's account of the functioning of his imagination seems to stand as a unique confession in the records of scientific discovery. The history of literary composition affords us, however, numerous parallels. Professor Dilthey of Berlin has gathered some of these together under the suggestive title "Poetic Imagination and Insanity." Some literary men, like Scribe, are gifted with vivid visual imagery, others, like Legouvé, are dependent for their success on auditory images. Scott, Victor Hugo, and Browning seem to belong to the motor type. There is evidence in the case of Flaubert, as well as in that of Zola, that literary imagination may derive its data from the chemical senses. An analysis of the writings of poets like Marston and Helen Keller, defective in sight, in hearing, or in both, is of particular value in the study of literary

imagination. Artistic creation in general employs imagery in order to preserve or enhance sensory experiences and to convey to others the moods of the artist.

Is there any class of human being in whom the imagination is more held in control, more disciplined, more subordinated to the reason, than it is in the adult scientist? All the psychic processes, including instinct and inspiration (which has been described as a sort of unconscious imagination), are means of establishing useful relationships with men and things, and it is by no means surprising that the scientific discoverer, who grapples with difficult problems of adjustment, should bring the finest powers of the mind into play. The history of science assures us that the creative imagination is not the monopoly of the painter, sculptor, poet, philosopher, or theologian.

Special investigations of the mental characteristics of Kepler, Newton, Davy, Faraday, Claude Bernard, Ehrlich, Weismann and others must be undertaken before an adequate psychology of scientific discovery can be formulated. The nature of the data of each science, as well as the mental make-up of the individual discoverers must be made the subject of rigid investigation. Kekulé's pupil Van 't Hoff, who at the age of twenty-two wrote the essentials of *La Chimie dans l' Espace*, seems to have shared the visual imagination of his master. For Kolbe the idea that the arrangement of atoms in molecules could be determined appeared almost as fantastic as a belief in witchcraft or spiritualism. Berthelot was not less disdainful concerning Wurtz, the teacher of Van 't Hoff and Le Bel. When some friend told Berthelot not to take the atomic theory too seriously, atoms having no objective reality, Berthelot growled: "Wurtz has seen them!"

The imagination, predominant in one type of scientific discoverer and restrained or suppressed in other types, is at best only one phase of creative thought.

THE SHORTHAND ALPHABET AND THE REFORMING OF LANGUAGE

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EVERY writer of shorthand—and there are now legions of them—must have wished, not only that others could write with as much ease and rapidity as himself, but also that there could be as short and accurate a system of printing as he has of writing. Why should we not make use of the shorthand alphabet not only for short writing, but also for short printing (either by hand or press), and a short, direct means to the correct pronunciation of new words?

Isaac Pitman, who invented the system of shorthand now most generally used among English speaking peoples, entertained this idea, and approved it, but never applied it. This paper presents an original plan for adapting the shorthand alphabet to printing, summarizes the results of an experiment in teaching children to read matter printed in this new form, and points out the tremendous educational and social advantages that would accrue if this new type of paper-language were in general use.

According to Isaac Pitman's analysis, there are forty sounds in the English language, twenty-four consonants, twelve simple vowels, and four diphthongs, or double vowels. Adopting (substantially) the Pitmanic symbols, we may represent these sounds as below.

CONSONANTS

\ = p as in pop
\ = b as in bob
| = t as in tat
| = d as in did
/ = ch as in church
/ = j as in judge
— = k as in kick
— = g as in gig
(= f as in fife
(= v as in vivid

VOWELS (SINGLE)

(The vertical line is not a part of the vowel symbol, but is used to represent any consonant stroke. A vowel symbol, as a heavy or light dot, stands for different sounds according to its position.)

|• = a as in pa
|• = a as in may
|. = e as in we
|– = a as in all

(= th as in thick
(= th as in that
) = s as in sit
) = z as in zoo
= sh as in ship
= zh = z as in azure
= m as in mum
= n as in noon
= ng as in sing
= l as in lily
/ = r as in rare
C = w as in will
U = y as in yes
= h as in hay

= o as in go
= oo as in too
= a as in that
= e as in pen
= i as in is
= o as in not
= u as in much
= oo as in good

DIPHTHONGS (DOUBLE VOWELS)

= i as in lie
= oi as in boil
= ou as in foul
= eu as in feud

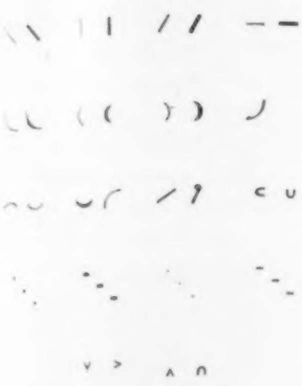
This gives us a perfect alphabet, neither redundant nor defective.

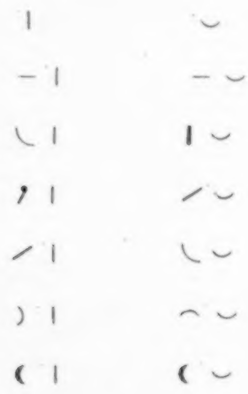
In writing shorthand, the consonant characters of a word or phrase are joined together, and the vowels are placed in a certain relation to the consonant strokes, that is, at the beginning, middle, or end of them. The vowel sign has a different sound according to its position. The plan here presented for adapting this alphabet to printing introduces two variations: the consonants are kept disjoined; and the vowels are placed, not at the beginning, middle or end of consonant strokes, but in high, middle, or low position with regard to the line of print. This adapted alphabet, and matter printed in it, will be referred to as Fonoline.

An illustration will make the matter thoroughly clear. Figure 1, which presents three charts used in teaching fonoline to children, shows the symbols used in the fonoline alphabet, and the appearance of words printed in fonoline.

Although various experiments have been made in teaching reading by means of a phonetic alphabet, it appeared worth while to teach a group of beginners to read fonoline, partly to find the degree of effort necessary to learn it, partly to discover whether there would be any difficulty in passing from fonoline to a-b-c English. Should we as a race ever wish to change our alphabet (as the Chinese are doing), this latter question would probably become very important.

Accordingly, fonoline was taught to a group of twelve pupils in a first grade, whose Stanford-Binet intelligence quotients ranged from 75 to 127, with a median of 87.5. In physique and power of application, they were probably somewhat below the





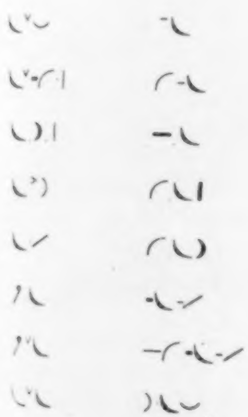


Fig. 1. Three charts, reduced in size, used in the teaching of fonoline. The chart at the upper left shows the fonoline alphabet, omitting the symbol for the sound of zh, which was not used in the first grade vocabulary. The words on the other charts are as shown below, and in the same order.

Words on Chart at Upper Right.

at	an
cat	can
fat	Dan
hat	ran
rat	fan
sat	man
that	than

Words on Chart at Left.

vine	of
violet	love
visit	give
voice	lived
very	lives
have	over
hive	clover
five	seven

average. They were taught, in the East Stroudsburg State Normal Training School, by two cadet teachers and myself, no one of us having ever before taught a child to read. There was some difficulty also in procuring the necessary type and other materials for keeping the experiment going.[1]

At the end of a month (spending a little over an hour a day on the subject), twenty-three sounds had been introduced, and the pupils were attacking new words with fair success. A week later, the brighter pupils were separated from the rest and began

[1] In reporting this experiment, I wish to make acknowledgment of the receipt of financial aid by means of which it was promoted from the American Association for the Advancement of Science.

Acknowledgment of substantial assistance of a different kind is due to Mrs. La Rue, without whose help the necessary reading material could not have been composed, illustrated and printed.

reading such stories as "The Little Red Hen" without the aid of the teacher. At the close of eleven weeks, our advanced class had learned all the symbols, had read about one hundred fifty pages of the Fonoline Primer, and could readily master, independently, any new word of not more than five or six symbols (that is, five or six sounds when spoken), unless it involved some peculiar difficulty. As few words in the first grade vocabulary reach this length,

THE CAT AND THE MOUSE

A wee mouse was eating.

A cat saw her.

The cat said,

"I must have that mouse."

Then away she went.

Fig. 2. Showing fonoline used interlineally to aid in the introduction to a-b-c English. The words that have no fonoline beneath them had already been mastered by the pupils before reaching this story.

we thought it best to pass from this grade of attainment to the study of a-b-c English. At the end of fifteen weeks, the slower section also (containing, it will be remembered, some retarded pupils) having covered all their symbols and read over one hundred pages of the Primer, proceeded to the study of a-b-c English.

Passing from fonoline to ordinary English introduced practically no new problems except those which are always incident to the teaching of reading in English, and we of course used our "perfect" phonetic alphabet to aid in the mastery of the imperfect, partially unphonetic one. The first means employed was that of interlinear printing, placing the a-b-c English above and the corresponding fonoline just below as a key to pronunciation, as shown in the figure. As soon as a word had appeared in the a-b-c type a few times, it was left without the fonoline aid to pronunciation beneath it, whereupon the pupil either remembered it or was forced to go back and find it where it had last appeared.

At the close of the year, our pupils had accomplished, so far as we were able to judge, substantially the same amount of work in a-b-c English, after spending the first ten or fifteen weeks on fonoline reading, as they would have done had they spent the whole year on a-b-c English; that is, their achievements were on a level with those of preceding classes, the time devoted to reading remaining unchanged. Our advanced class won the special commendation of the State examiner, who had no knowledge of how the grade had been taught.

We are inclined to believe that fonoline forms a good introduction to a-b-c English, and that if it could replace the usual system of diacritical marking, time would ultimately be gained through its use. We consider it quite safe to assert that if a pupil of average intelligence and application were given a year of instruction in reading fonoline (especially if there were devoted to reading the two hours per day commonly assigned to it in our city schools), such a pupil would then be able to read anything (printed in that alphabet) which he was capable of understanding. Beyond reviews, no further work in reading would be necessary for one so taught except to train him in the apt expression of those thoughts and feelings which would come to him with maturity. And he would not only know how to read: he would be able to find in the fonoline dictionary any ordinary word that he could pronounce. Further, he could "spell," both orally and in writing (fonoline characters) any word that he could turn his tongue to.

Let us now give our attention to the educational and social advantages that would be ours if such an alphabet as fonoline were brought into common use. Let us keep in mind, too, that

fonoline is advantageous beyond any other phonetic alphabet; for it bears a unique relation to Pitmanic shorthand, the most speedy and efficient means yet devised by the human brain for passing its thoughts down through hand and pen and so recording them on paper.

First, then, does fonoline present an alphabet which adequately represents the sounds of spoken English? We can sum up this matter admirably by quotations from Max Muller: "What I like in Mr. Pitman's system of spelling is exactly what I know has been found fault with by others, namely, that he does not attempt to refine too much, and to express in writing those endless shades of pronunciation, which may be of the greatest interest to the student of acoustics, or of phonetics, as applied to the study of living dialects, but which, for practical as well as for scientific philological purposes, must be entirely ignored . . . . Out of the large number of sounds, for instance, which have been catalogued from the various English dialects, those only can be recognized as constituent elements of the language which in and by their difference from each other convey a difference of meaning. Of such pregnant and thought-conveying vowels, English possesses no more than twelve. Whatever the minor shades of vowel sounds in English dialects may be, they do not enrich the language, as such; that is, they do not enable the speaker to convey more minute shades of thought than the twelve typical single vowels . . . . If I have spoken strongly in support of Mr. Pitman's system, it is . . . . chiefly because it has been tested so largely and has stood the test well."[2]

Next, if the number of our characters is correct, is their form satisfactory? As to the advantages of simplicity, perhaps the work of Broca and Sulzer can be accepted as authoritative. These investigators concluded that both our letters and the words of which they are composed would be more easily recognized and quickly read if they were simplified in form. "Practically," they report, "the recognition of a letter demands an expenditure of energy that is greater as its form is more complex. Thus we read a V, a T, or an L more easily than an E or a B. From the standpoint of speed of reading and also of the cerebral fatigue caused by the act it would be better to employ simpler letters than those now used. We have thus been led to seek the least complex possible forms, and we have concluded that, for capital letters, they are those shown in Figure 3. For the small letters, where there

[2] From an article in the *Fortnightly Review* of April, 1876, as quoted in *The Life of Sir Isaac Pitman*, by Alfred Baker, p. 206.

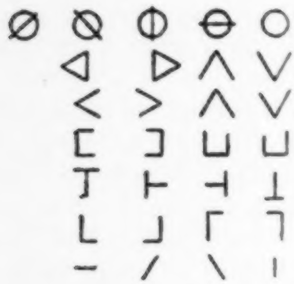


FIG. 3. Showing the simple capitals proposed by Broca and Sulzer.

are two sizes, and two positions with respect to the line, the solutions are more numerous and some are shown in Figure 4.

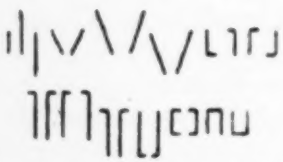


FIG. 4. Simplified small letters proposed by Broca and Sulzer.

"We do not wish here to go farther into this question and ask whether it would be worth while to change our present alphabet; but we desire only to point out that these characters, derived from the Phenician alphabet, are not scientifically as perfect as could

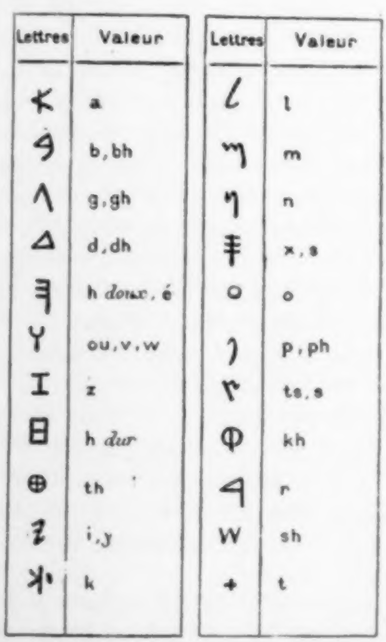


FIG. 5. Alteration of modern from ancient letters.

be wished. A glance at Figure 5 shows that all the changes made in transforming the old alphabet into ours are far from being simplifications."[3]

So far as capitals are concerned, whether simplified or not, they should be dropped altogether. In the teaching of fonoline, we omitted them and never missed them. Further, we were only embarrassed by them, as every teacher of primary reading is, when they appeared in the a-b-c English. The Germans distribute their complex capitals lavishly, to the exasperation of the reader (speaking for myself). The French tendency is better, to omit them as much as possible. Neither the writer nor the reader of shorthand commonly misses capitals or wishes for them. They only make him trouble. Had we grown accustomed from our youth to the use of small letters only, we should then have had the right attitude toward capitals, namely, that they are a useless and expensive luxury; and we should have rejected at once any proposal that they should be introduced into our language. As matters are, we ought to welcome the possibility of further simplifying our alphabet by reducing it from fifty-two characters to forty.

A further question of interest is, do words printed in fonoline have sufficient character and individuality to insure their quick recognition in rapid reading? Students of the psychology of reading seem to agree that glance recognition, as we may call it, depends chiefly on the length of a word, on its consonants, especially those that are so tall as to stick up above the general body of the word, and on its first letter or letters, which, as they strike the eye, serve as a kind of key to the part that follows. It is evident that words would have characteristic lengths and first-letter keys, no matter what alphabet were used. The great importance of the consonants in furnishing the skeletons of words and so giving them characteristic shape must long have been felt, even if not consciously reasoned out; for the Hebrews, centuries ago, left the vowels out of their words and still found them, for the most part, easily legible. The modern writer of Hebrew either fills in his vowels or omits them, as he pleases. So does the writer of Pitmanic shorthand. When writing under speed, he puts in only an occasional key vowel, yet finds his writing easily readable. The joined consonants of a word form an "outline" which flashes into his mind instantaneously when he hears that word pronounced, and which he recognizes at once when he sees it on paper.

I venture to assert that this advantage is carried over, in large

[3] This report was published in *La Nature*, Paris, February 13, 1904. The quotation and figures given above are taken from a translation printed in *The Literary Digest* of March 12, 1904.

measure, into matter printed in fonoline. The rapid reader, guided largely by context, as such readers always are, would find his words taking on such a characteristic consonantal shape that he would have little use for the vowels. The consonants would form the chief mass of the average word, and in the great bulk of cases would protrude either above or below their adjacent vowels. Yet if there were doubt in any case, as there might be when two words contained the same consonants in the same order, the vowels would be there to give their voice and settle the matter. But to vowels, generally, we should apply a rule in contrast with that which we apply to children: the vowels should be heard and not seen too conspicuously.

If it should prove desirable to indicate the accent of words, this could be accomplished by any of several simple methods, and in a manner which would cause printers no difficulty.

Let us now consider, but very briefly, how and how much we could shorten and enrich the work of the elementary school through the use of fonoline.

Learning to read would become so easy that many children would learn at home. (One of our pupils retaught a part of her fonoline lessons to her little brother.) At any rate, independent reading, on the part of the average child, would begin before he had spent more than a few weeks in school; and he could then advance, by silent reading, at his own pace, taking up one form of literature after another as fast as he was able to appreciate it.

The subject of spelling would disappear from our programs of study, leaving the time now devoted to it to be turned to some useful purpose. Like the Italians and the Spaniards, we should then have no spelling books in our schools.

The use of the dictionary would never have to be taught as at present; for since, with a phonetic alphabet, the pronouncing of a word is equivalent to the spelling of it, one could readily find in the fonoline dictionary any word that he could pronounce. Not only could any one master his own language quickly, but when foreign tongues were undertaken, he could use what would then be his native alphabet as an aid to the mastery of them also. A "phonetic transcription" would cease to be in any way formidable and would become wholly a help if one could indicate the pronunciation of strange-looking foreign words by using the familiar characters of his own alphabet. An enterprising and scholarly minister, father of one of our pupils, made use of her knowledge of fonoline to introduce her to Hebrew, in which language he was anxious to give her an early start. Pitman's shorthand has been adapted to twenty-one foreign languages, including Latin, and

also to Esperanto. Should any peculiar sound of a foreign tongue require a new symbol, then, it would very likely be ready to hand. Indeed, I do not consider it too wild a dream to hope that *the Pitmanic shorthand alphabet may some day serve as the common alphabet for all the languages of the earth.* I leave others to deduce the various results of this, and will here only remark that I should consider it a very long step toward a universal language, a step which, while suppressing no language, would very likely result in preserving the best elements of all.

In the subject of writing, fonoline, through its relation to shorthand, would secure advantages which no phonetic alphabet not so related to "the winged art" could gain for us. As matters are, we teach our pupils four different forms for each of our twenty-six letters; these are the printed small and capital letters, and the corresponding written forms. Of course, these four forms are sometimes similar, as in the case of the letter *o;* but again they are quite at variance, as with *d, e, g,* and *l.* With fonoline in use, all this extra and useless learning, together with the whole subject of writing as we now know it, would drop out of existence. Judging as well as I can from the very limited amount of writing fonoline which was done by our experimental class, I should say that, if pupils were given a regular daily period of such practice, they could by the end of the first year in school write anything, expressed in the words of the usual first grade vocabulary, which they would be likely to utter. With a very moderate amount of practice as compared with what is necessary for the learning of ordinary writing, they could write at least as fast as they now do the longhand, and probably considerably faster. There are advantages of position and movement also, which conform more nearly to that which is naturally adopted by young children. For pupils of low mentality, this might be the limit of attainment.

For those who were ordinarily bright of mind and facile in learning, however, it would be but a small beginning. From fonoline the learner could pass, by the gradual and easy introduction of shorthand principles, to shorthand itself. This would be accomplished by such means as the joining of consonant strokes wherever convenient, and the introduction of shortening devices so familiar to the writer of phonography, such as the s-circle and the hooks at the beginnings and endings of strokes. The abbreviated signs for our most common words could also be taught, signs which would soon enable the pupil to write, in the shortest kind of shorthand, more than fifty per cent., of all the language he ordinarily used.

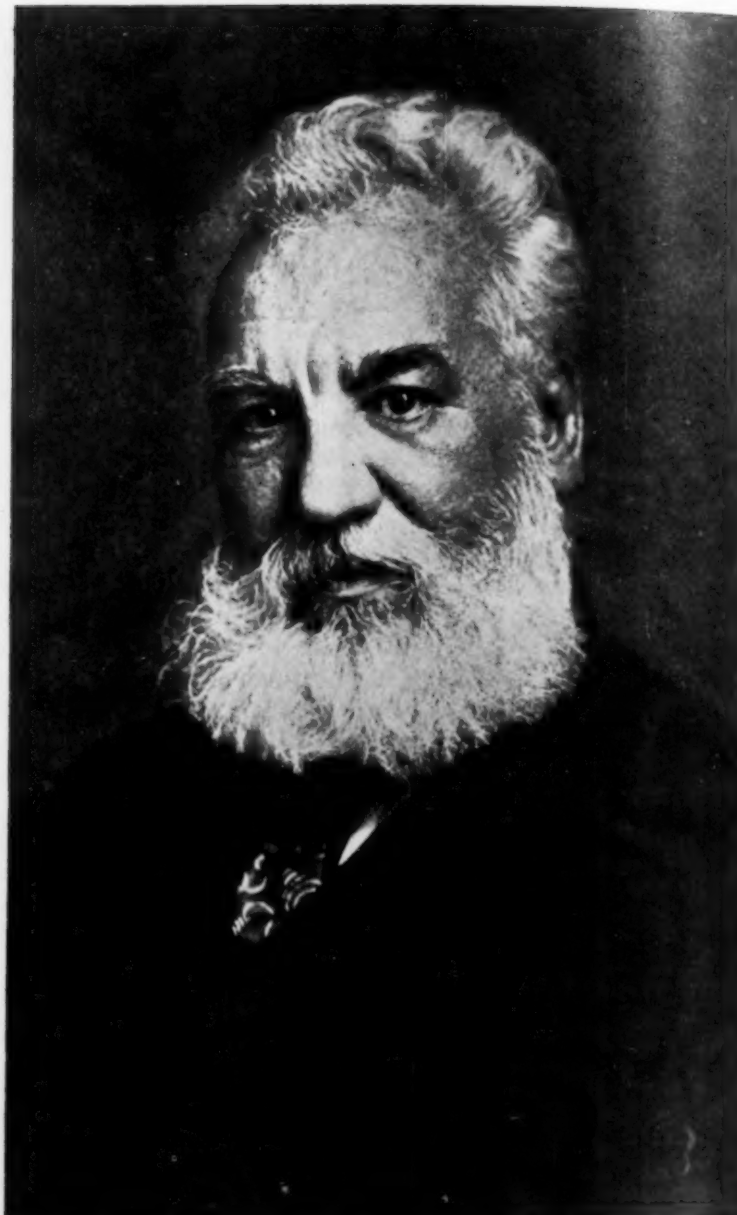
If such a course as I have described were preceded and accom-

panied by fonoline reading, and if we gave to it up through the grades the time which is now devoted to writing, I believe it safe to say that pupils would then be able to write no less than four times as fast as they now can with our cumbersome longhand, and with equal, or even greater legibility.

In the life outside of school there would result great savings in the printing of the language, in typewriting and linotyping, in teaching the feeble-minded, in the problem of Americanization, in progress toward a universal language, and in many other ways.

But the greatest argument, least appreciated because hardest to appreciate, lies, perhaps, in another direction. It is that a quicker alphabet, as we may call it, would make mankind more thoughtful and more social. The mathematician could never have made the progress he has in dealing with number and quantity had he not invented a shorthand method of expressing and working with them. The physicist and the chemist have their shorthand. What scientist does not? Is not this one of the distinguishing features of the modern use of symbols, to concentrate a great bulk of meaning in such brief form that we can hold it all in one grasp of consciousness, reason with it in every way as an inclusive unit of thought work? But of this argument we can offer no more than a suggestion.

Had such an alphabet as fonoline been in common use for the brief span of a century or so, no argument to return to our present slow and cumbersome methods would be heeded for a moment.



—*Wide World Photos.*

ALEXANDER GRAHAM BELL

In whose death at the age of seventy-five years America loses its great inventor and man of science.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service

WE WANT WATER

This is the season of the year when we appreciate the fact that our bodily substance is mostly composed of water. Lucky for us that it is, for water is not only the most abundant, but the most even tempered of liquids. It is slowest to cool and, what is of more interest just now, it is slowest to heat. It is this thermal conservation of water, otherwise known as its specific heat, that keeps us going regardless of the weather. For we can only live within the narrow rang of two degrees Fahrenheit, and it requires a delicate adjustment of the mechanism to maintain that temperature as we roam from the equator to the pole, or as the climates of these regions alternately roam over those of us who live in the north intemperate zone.

It is water that keeps all parts of the body at the same temperature in all weathers by circulation, and then in hot weather like this reduces the temperature by evaporation. So as a man on a pleasure excursion has to put a bill into his pocket from time to time to compensate for the sum imperceptibly evaporated in small change, so we require frequent invoices of water to keep up with the increasing retail outgo. The body in summer time is a steam engine, constantly taking advantage of the high rate of exchange between liquid and gas.

For water is twice blessed. It gives a blessing as it comes and as it goes. And the latter is the greater, though we are not so grateful for it. We appreciate the coolness of a glass of ice water, but it does us fifteen times as much good afterward as it escapes through a million pores. A cup of hot tea also may cool us off, for it takes away with it in evaporation from the skin fifty times as much heat as it brought to us.

Water is really what is wanted, although we add various flavors, call it by various names, and charge various prices for it. And it does not matter much what its initial temperature is, it will serve its purpose just the same. The only important thing is to get enough of it at all times, before meals, after meals, between meals and at meals. One can hardly get too much of it, but one usually gets too little.

The regulation of the strength of the various fluids of the body is as nicely adjusted as the equilibrium of temperature. But both are dependent upon an abundant supply of water. An excess can be easily disposed of but a deficiency upsets the machinery. A pound of water a day is about what the body can manufacture in its internal laboratory from the hydrogen of the food and the oxygen of the air, but this is not nearly enough to run it. The automobilist cools down his combustion cylinder by wrapping it with water and keeping this in rapid circulation. We also are propelled by an engine using food as fuel in much the same way and we use the same device to prevent overheating. But we have to evaporate the water to get the full cooling effect and this tends to dry us up, to make mummies of us, to leave us stranded for want of water.

Our thirst is thus the longing of the salt that is left behind for the water that has departed. It is a sort of homesickness, a longing for an ancestral habitat. For Venus Anadyomene is a verified myth. All

—*Wide World Photos.*

SIR JOSEPH JOHN THOMSON, THE DISTINGUISHED ENGLISH PHYSICIST, RECEIVING THE FRANKLIN MEDAL FROM LORD BALFOUR

life sprang from the sea. And the tide that ebbs and flows through our heart is composed of much the same elements as the ocean from which it was originally dipped.

SHORT NAMES

When a man makes a new invention his work is not done. He should invent a new name for it. Here he is apt to fail for, being more of a mechanic than a philologist, he turns over the job to the Greek professor who manufactures one out of old roots. So it happens that many a handy little pocket tool is handicapped by a name that wraps three times around the tongue. But the people refuse to stand for it.

Consider what a Babel-like botch has been made of the job of naming the new art of photographing action. Rival inventors, rival word-wrights, and rival systems of Greek transliteration precipitated a war of words in which the chief belligerents were animatograph, animatoscope, biograph, bioscope, chronophotography, cinema, cinematograph, cinematoscope, cineograph, cineoscope, electrograph, electroscope, kinema, kinemacolor, kinematograph, kinematoscope, kineograph, kineoscope, kinetescope, motion pictures, moving pictures, photo plays, tachyscope, veriscope, vitagraph, vitascope, zootrope, zoogyrograph, zoogyroscope, and zoopraxiscope.

But the people—they call it "the movies." It is not a great name, but it is better than some at least of those listed above.

If, instead of trying to load the new machine with a name implying that it had been invented in Athens or Rome, its godfathers had given it a respectable convenient name of one or two syllables like "volt," "kodak," or "velox," much of this confusion might have been saved. Think how many millions of dollars, years of time, barrels of ink and cubic miles of hot air would have been saved if "electricity" had been named in one syllable instead of five. We might even now cut it down to "el" except that by popular vote the six syllables of "elevated railroad" have been reduced to that handy term. So, too, the people have found a way to reduce "radiotelephony" to a single mouthful, "radio."

The lesson of it is that if the father of a new invention does not want to have his child called by a nickname let him give it a short and snappy name on the start.

MEDIUMS AND TRICKSTERS

Those who believe in spiritistic phenomena call upon their opponents to disprove their hypothesis, and hold, rightly enough, that if ninety-nine mediums are merely tricksters, it does not prove that the hundredth is not genuine. It is, of course, impossible to prove the universal negative of such a proposition. It is merely a question of probabilities. We can merely say that if spirits do return, it is extremely unfortunate that they can only return under those conditions which are most favorable for deception.

What these conditions are we can learn from the practices of amateur and professional conjurers. Let us approach the matter from another starting point than is usually adopted. Instead of speculating as to how departed spirits would manifest themselves to us, a matter which we can know nothing about, let us consider what a trickster would do if he wished to deceive the public into thinking that he was possessed of spirit power, a matter on which we have unfortunately a great deal of information. What conditions would he impose? What methods would he use? The following are the chief characteristics of such fraudulent manifestations:

(1). Darkness. The less the light

EDMOND PERIER

In whose death France loses a distinguished zoological leader. Mr. Perier, who was director of the Paris Museum of Natural History, is photographed in the official dress of members of the Paris Academy of Sciences

the more remarkable the manifestations is the general rule.

(2). Distraction of attention. This is the chief reliance of the parlor and stage magician. The most striking things in the seance room occur after the sitters are tired of watching.

(3). Unexpectedness. An experimenter lets us know what effect he is trying to get, and even if the experiment does not work he does not palm off some entirely different phenomenon and claim he has succeeded. The feats of the conjurer—and of the medium—are capricious and unforeseen. That is why trickery can not be guarded against by precautions in advance.

(4). Control of conditions. The conjurer and the mediums alike insist on having lights, furniture, sitters and apparatus arranged to suit themselves. On the other hand, the primary requisite of an experiment is the control of conditions. It is therefore, incorrect to speak of experiments with mediums. They are usually merely observations, and that under circumstances most unfavorable to correct observation.

(5). Suggestion. This is the main reliance of the magician, next to distraction of attention. He palms a coin while pretending to throw it into a hat or into the air. Our eyes follow the motion of his hand and interpret it according to the intent. It is easy under favorable circumstances to cause collective hallucinations of smell, sight or sound. Our sense of hearing is particularly liable to be deceived as to the character and direction of a sound, such as the raps and scratches which are the commonest of mediumistic phenomena.

(6). Concealment. A prestidigitator for his most difficult tricks requires some kind of a table, shelf or screen, but he rarely demands so convenient a shelter as the medium's cabinet or curtain.

(7). Tied or held hands. The releasing of hands and feet when they are bound, knotted and sealed is the cheapest of tricks. I have seen a man handcuffed by a policeman, tied in a bag and thrown into the river, yet he came to the surface promptly with his hands free.

(8). Involuntary assistance. The respectable and well-meaning gentlemen whom the audience select to represent them on the stage do not interfere with the magician. On the contrary, they often aid as well as give countenance. The magnetic girl who used to throw strong men about the stage was really utilizing their strength, not her own. Where several persons have their hands on a table it is impossible to prevent their taking an active part in its motion.

(9). Emotional excitement. An experimenter must preserve a cool and somewhat detached demeanor. Now, even the most convinced skeptic can not witness unmoved such violations of natural law as these, purporting to prove the existence of another world, and especially the presence of his deceased friends and relatives. The photographs taken of the seance room show us not merely that the table is suspended in mid air, but that the witnesses, watching it with bulging eyes, open mouths and strained attention, are incapable of critical observation.

In these nine points and others the conditions of successful trickery and the conditions of the seance are the same. For that reason and others most scientists do not think it worth while to spend their time on spiritualism.

MIND-CLEANING TIME

Housecleaning time, when every article of furniture from cellar to garret is handled and dusted, occurs traditionally each spring. An annual purification of the spiritual nature, when we overhaul and furbish up our morals, is set by all the churches.

We are urged to subject ourselves to periodic physical examinations.

Yet it is quite as important to keep our minds in good condition as our houses, our consciences or our bodies. Error is as contagious as disease. A false belief may make more trouble in the world than a wrong intention.

Vacation is a good time to overhaul your brain from the frontal lobe to the cerebellum. Review your axioms, revise your postulates, and reconsider the unexpressed minor premises of your habitual forms of logic. All your reasoning, however correct, all your knowledge, however great, may be vitiated by some fundamental fallacy, carelessly adopted and uncritically retained. Get a lamp and peer into all the dark corners of your mind. No doubt, you keep the halls and reception rooms that are exposed in conversation to your friends in fairly decent and creditable order. But how would you like to let them look into your cerebral garret and subliminal cellar, where the toys of childhood and the prejudices you inherited from your ancestors mold and rot?

Hunt out and destroy with great care every old rag of superstition, for these are liable at any time to start that spontaneous combustion of ideas we call fanaticism against which there is no insurance. The bigger the brain the more dangerous such things are, for they have the more fuel. A little decaying superstition in the mind of a great man has been known to conflagrate a nation.

Errors breed errors. They multiply like microbes, especially through neglect. A single false belief may infect all the sound facts you pile in on top of it. Better an empty room than a rubbish heap. In the words of our American philosopher, Josh Billings, "it is better not to know so many things than to know so many things that are not so."

Go systematically through your intellectual equipment and see wherein it is deficient. Add annuals to your mental cyclopedia. Pick up each one of the sciences where you left off at school and bring it down to date. Look over the fields of art and literature to see what you have missed or misconceived. Don't let your sociology get too far behind the age. See that your philosophy and psychology bear the same date as the calendar. Examine your religious creed in the light of modern knowledge to see if it needs revision. Take down the atlas and consider how long it has been since you heard from each country. Visit the planets in turn. Take another view of ancient history through the telescope provided by modern scholarship.

This inspection of one's stock of ideas is necessary because they do not keep as if they were in cold storage. They do not remain unchanged when stored away and neglected. There is a lot of thinking going on in our brains that we do not know anything about. Ideas are apt to sprout or spoil, like potatoes in a cellar. Facts will ferment from yeasty thoughts until they intoxicate the brain. Falsehoods generate ptomaines, poisoning the mind and producing inexplicable disease and death. You can not be too careful. Clean out your mind at least once a year.

SCIENTIFIC ITEMS

We record with regret the death of Alexander Graham Bell; of Simon Nelson Patten, long professor of political economy in the University of Pennsylvania; of Jokichi Takamine, the industrial research chemist; of Jacobus Cornelius Kapteyn, professor of astronomy at Groningen; of Wilhelm Wislicenus, director of the chemical laboratory at Tübingen; and of Jacques Bertillon, the French statistician.